Science Europe Briefing Paper

on Citizen Science

June 2018

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Shaping the future of research

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Summary

Citizen science, also referred to as community science or public participation in scientific research, is a growing movement that enlists the public in scientific discovery, monitoring, and experimentation across a wide range of disciplines.

The term citizen science was first used in the mid-1990s by social scientist Alan Irwin in the UK to emphasise the responsibility of science to society, and by ornithologist Rick Bonney in the US to describe the contribution of citizens to observations or efforts to the scientific enterprise. There are different approaches to categorising citizen science projects depending on participation, investment of time and resources, project approach, and depth of engagement.

Citizen science is increasingly considered as a discipline in its own right. Since around 2010 there has been a significant increase in published articles from citizen science projects. Main fields of study are biology, ecology, and conservation, with the largest scientific output in ornithology, astronomy, meteorology, and microbiology.

The practice of citizens performing science and of scientists working together with citizens occurs in many different countries and in many different ways. It predates the use of the term 'citizen scientist' or 'citizen science' and is on the increase around the world. In some countries, for example Austria and Switzerland, the term 'citizen science' is so novel that it is not translated. Citizen science is widespread in the US, which has the highest percentage of members of the Citizen Science Association. The US is relatively advanced in policy support for citizen science, including within government agencies. The most coherent voice for citizen science in Europe is the European Citizen Science Association (ECSA). Of all EU member states, Germany is arguably most advanced in its citizen science policy.

Citizen science is described by the European Commission under Open Science. It has commissioned White Papers, Green Papers, and In-depth reports on citizen science. In reality, the JRC of the EC 'practice' citizen science. A survey on EU-wide citizen science conducted in 2016 reveal the vast majority of projects participants located in the UK and Germany with most projects in the field of life sciences and most funding coming from national sources. There are 1000s of examples of citizen science active, inactive and open for participation projects.

Citizen Science is a developing tool for expanding scientific literacy. In combining research with public education, citizen science addresses broader societal impacts by engaging members of the public in research at various stages in the scientific process and using modern communications tools of participation. The general public support citizen science but are more confident in science findings from professional scientists. When scientists collaborate with citizens, they are motivated mostly by their interest in promoting research and obtaining funding as opposed to a desire to engage with the public.

Over the past 20 years, several new developments in information science – especially in data informatics, graphical user interfaces, and geographic information system-based web applications, have been vital to the emergence of citizen science. Future projects will be increasingly networked using open science and online computer/video gaming as important tools to engage non-traditional audiences. A more formalised approach of citizen science is emerging with networked organisations, associations, journals, and cyberinfrastructure that will help address issues such as prioritisation, peer-review, intellectual property rights and sustainable funding.

The Evolution of Citizen Science: Definition, Categorisation, and Academic Recognition

A policy report[1] cites the first recorded example of the use of the term 'citizen science' as being by R. Kerson in the magazine MIT Technology Review from January 1989[2] with a description of how 225 volunteers across the US collected rain samples to assist the Audubon Society in an acid-rain awareness raising campaign. The volunteers collected samples, checked for acidity, and reported back to the organisation. The information was then used to demonstrate the full extent of the phenomenon.

It is, however, generally cited that the term citizen science was first used in 1995 by social scientist Alan Irwin in the UK (currently Professor at the Department of Organisation, Copenhagen Business School) to describe expertise that exists among those who are traditionally seen as ignorant 'lay people'.[3] Irwin described two dimensions of the relationship between citizens and science: 1) that science should be responsive to citizens' concerns and needs; and 2) that citizens themselves could produce reliable scientific knowledge. The ornithologist Rick Bonney in the US (currently Director of Programme Development and Evaluation, Cornell Lab of Ornithology, Cornell University), unaware of Irwin's work, defined citizen science as a research technique in which non-scientists voluntarily contribute scientific data to a project.[4] This describes a more limited role for citizens in scientific research than Irwin's conception of the term.

Cooper and Lewenstein[5] discuss these two meanings or strands of citizen science. The first strand, from Irwin's definition, emphasises the responsibility of science to society, which they call "democratic" citizen science. At the other end of the spectrum, the second strand, is "participatory" citizen science in which people mostly contribute observations or efforts to the scientific enterprise, a meaning that originated with Rick Bonney's (1996) work at the Cornell Lab of Ornithology. Bonney[6] suggests that future iterations of the citizen science definition should highlight the diversity, scale, and value of citizen science projects from both strands. Ceccaroni et al.[7] focus on the convergence of these viewpoints to define citizen science in relation to civic education as work undertaken with citizen communities to advance science, foster a broad scientific mentality, and/or encourage democratic engagement, which helps society address complex modern problems.

In 2005 Wikipedia defined citizen science as "a project (or ongoing program of work) which aims to make scientific discoveries, verify scientific hypotheses, or gather data which can be used for scientific purposes, and which involves large numbers of people, many of whom have no specific scientific training."

The term citizen science entered the Oxford English Dictionary in June 2014, defined as "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions." This definition fails to consider the broader use of the term as initially coined by Irwin. A 'citizen scientist' is defined as: (a) "a scientist whose work is characterised by a sense of responsibility to serve the best interests of the wider community (now rare)"; or (b) "a member of the general public who engages in scientific work, often in collaboration with or under the direction of professional scientists and scientific institutions; an

amateur scientist." The first use of the term 'citizen scientist' can be found in the magazine New Scientist in an article about ufology from October 1979.[8]

There are different approaches to categorising citizen science projects. In a review[9] of over 200 citizen science projects, scientists working on behalf of the UK Environmental Observation Framework split environmentally-focused projects described as citizen science according to their degree of mass participation (local or mass) and 'thoroughness' (a measure of investment of time and resources). Other strategies classify citizen science projects according to their approach. Wiggins and Crowston, for example, propose a typology[10] dividing citizen science into action, conservation, investigation, virtual, and education. Haklay's scheme[11] classifies citizen science projects based on the depth of their engagement with volunteers, within a four-level framework of participation. At level 4, so-called extreme citizen science, citizens are involved at all stages in the development of the project and work to achieve their own goals. Extreme citizen science can include projects where citizens are the driving force behind the research and professional scientists are not involved at all. Level 3 is termed participatory science. Participants are involved in steering the direction of the research from problem definition to data collection. Level 2 includes distributed intelligence. Projects include Galaxy Zoo and eBird (an online birding project), which may provide participants with some basic skills before asking them to collect and potentially interpret data. Finally, level 1 is termed Crowdsourcing. These are the least participatory projects and use volunteers simply as a means to collect data from distributed sensors, or to provide computing power. Table A shows how the three aforementioned schemes can be used to classify a select number of citizen science projects.

Table A Classifying citizen science projects

	Classifications		
Project and brief description	**Wiggins & Crowston**	**Roy et al.**	**Haklay**
Galaxy Zoo *Classifying images of galaxies*	Virtual	Mass Contributory	Level 2 Distributed Intelligence
eBird *Collecting bird observations*	Investigation	Mass Contributory	Level 2 Distributed Intelligence
What's Invasive *Locating invasive plants*	Conservation	Mass Contributory	Level 2 Distributed Intelligence
ReClam the Bay *Restoring local bay's clams and oysters*	Action	Local Community-led	Level 3 Participatory Science
Corfe Mullen Bio-blitz *Identifying species in Corfe Mullen village and local area*	Investigation/ Education	Local Co-created	Level 3 Participatory Science
Climateprediction.net *Volunteers' computers used to run climate prediction models*	Virtual	Mass Contributory	Level 1 Crowdsourcing

University College London's has an Extreme Citizen Science research group (UCL ExCiteS) that brings together scholars from diverse fields to develop and contribute to the guiding theories, tools and methodologies that will enable any community to start a Citizen Science project to deal with

issues that concern them. Their website[12] provides several examples of Extreme Citizen Science: the ExCiteS project[13] that ran from 2011 to 2016 demonstrated how non-literate people and those with limited technical literacy can successfully participate in formulating research questions and collecting the data that is important to them. ExCiteS started with the case of supporting Pygmy hunter-gatherers, local NGOs and other local indigenous partners to tackle illegal logging in the Congo basin. It quickly expanded to Namibia, Brazilian Amazon, and cases in the UK to support several local communities in their aim to combine their local environmental knowledge with scientific analysis to improve environmental management.

Citizen science is increasingly considered as a discipline in its own right. Examples of academic groups collaborating in this field include:

- **Citizen Cyberscience Centre**[14] is a Swiss partnership involving CERN, the UN Institute for Training and Research and the University of Geneva. Citizen Cyberlab develops and studies new forms of public participation in research. It initiates projects and organises events that encourage citizens and scientists to collaborate in new ways to solve major challenges.

- **Open Air Laboratories** (OPAL)[15] is a UK-wide citizen science network led by Imperial College London and the Natural History Museum in the UK. It develops activities and resources, including national surveys, which encourages participants to get closer to their local environment while collecting scientific data.

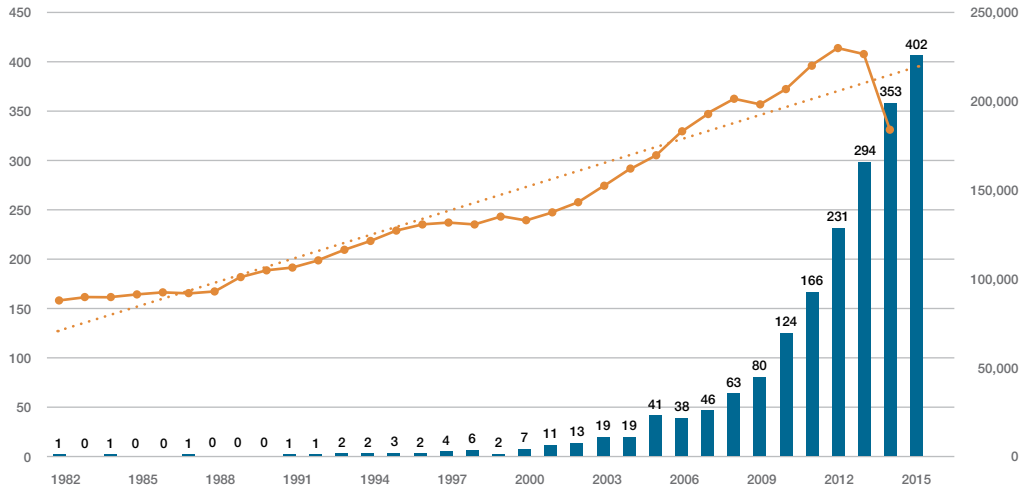

Figure 1 Growth of Citizen Science publications compared to Web of Science total. Source: Kullenberg and Kasperowski[16]

Until recently, the literature on citizen science has been scattered across scientific journals. Much of it exists under different labels, such as 'peer-to-peer' science, participatory science, community science, community based research, public participation in research, crowdsourced science, and so on. The diversity of literature and labels means that few practitioners or scholars realise how broad the field is. Most citizen science projects fall outside the scope of scientometric evaluation, since scientific output is not a main goal. However, Kullenberg and Kasperowski have recently analysed data from Web of Science to understand the evolution of citizen science.[16] They observe

a slow increase in the use of the concept from around 2000 (Fig. 1). From around 2010 there is a significant increase in published articles coinciding with several digital citizen science projects that use web-platforms such as Galaxy Zoo.[17] They find that main fields of study employing citizen science are to be found in biology, ecology, and conservation research, and increasingly in the social sciences and geography. In quantitative terms, the largest scientific output is to be found in the fields of ornithology, astronomy, meteorology, and microbiology.

In terms of prioritisation of research topics, although there are biases in citizen science sampling efforts relative to abundance on Earth, these biases are consistent with biases found in professional science (Figure 2).[18] For example, although occupation on earth increases from freshwater to terrestrial to marine areas, freshwater to terrestrial are far more popular than marine studies (see bottom right inset C in Figure 2).

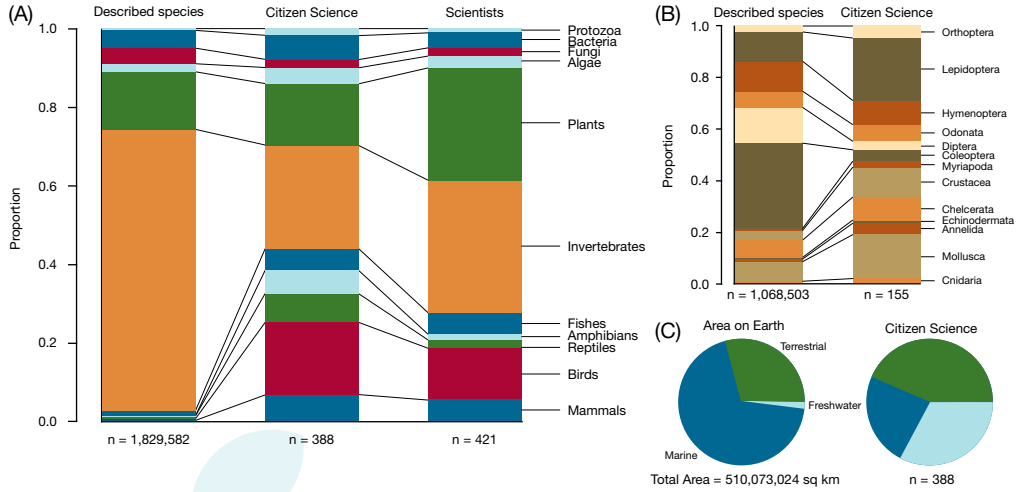

Figure 2 Taxonomic and ecosystem representation of citizen science projects relative to mainstream science. Source: Theobald et al.[18]

While the definition of citizen science and project categorisation is still under debate, it is clear that citizen science in practice and in theory have evolved over the past four decades. In the last two years, a transformation has occurred. Citizen science has appeared in Nature and in Science. New citizen science associations have begun in Europe, the United States, and Australia. A new journal, Citizen Science: Theory and Practice, has been launched. Citizen science is spreading all over the world.

Key messages

- The term citizen science was first used in the mid-1990s by a social scientist Alan Irwin in the UK to emphasise the responsibility of science to society and an ornithologist Rick Bonney in the US to describe the contribution of citizens to observations or efforts to the scientific enterprise.
- There are different approaches to categorising citizen science projects e.g. depending on participation, investment of time and resources, project approach, depth of engagement.

- Citizen science is increasingly considered as a discipline in its own right. Since around 2010 there is a significant increase in published articles from citizen science projects. Main fields of study are biology, ecology and conservation with the largest scientific output in ornithology, astronomy, meteorology and microbiology.

Citizen Science Around the World

As discussed above, currently, a wide variety of terms and expressions are being used to refer to the concept of citizen science. Eitzel et al. explore the geopolitical and language context of citizen science.[19] The authors review the theoretical, historical, geopolitical, and disciplinary context of citizen science terminology. They discuss what citizen science is, review related terms, and provide a collection of potential terms and definitions for 'citizen science' and people participating in citizen science projects.

Although the term citizen science was coined in the US and the UK, the practices of citizens performing science and of scientists working together with citizens occurs in many different countries. Therefore, various terms for this method exist (Table B). What most of the terms have in common is their language-specific word for 'citizen,' in the sense of 'inhabitant of a nation' (sometimes associated with legal attributes, or 'civil rights'), and the translation of the term 'science,' which characterises the scientific approach behind the activity.

In many countries, for example Australia, Austria, Brazil, Chile, Ireland, and the Arctic regions, citizen science was established by grassroots activities through a bottom-up approach, and the terms that practitioners in these geographies use echo this grassroots development. In Europe, citizen science is also driven by universities, research centers, and museums. Governmental support and/or structures are available only very recently in some countries (such as Austria), whereas in Germany and the US, the government currently funds and sometimes even runs citizen science networking activities and projects. Considering the social diversity involved in the grassroots origins of citizen science in many countries, it may not be enough to simply translate the term, because the history, context, and practices must be looked at more closely. In some countries, such as Austria and Switzerland, the term is so novel and unusual that it is not translated at all, and the meaning of 'citizen science' is adapted to the country-specific context.

Table B The geopolitical and language context of Citizen Science

Region and name	Description
Arctic regions *Traditional Ecological Knowledge (TEK)*	The term 'Citizen Science' is rarely if ever used for research in these regions, perhaps due to the existence of the Arctic Council, which has promoted co-operation, co-ordination and interaction among the Arctic States, Arctic indigenous communities, and other Arctic inhabitants on common Arctic issues, in particular on issues of sustainable development and environmental protection in the Arctic for the last 20 years.
Australia *Citizen science*	Members of the public have contributed to scientific research in Australia for decades. However, the term 'citizen science' and the ubiquity of such activities was relatively unknown until recently. Citizen science leaders recognised the need to connect this community, which led to the formation of the Australian Citizen Science Association (ACSA, http://www.citizenscience.org.au) in May 2014 and the first Australian citizen science conference in July 2015. To date, citizen science activities have been identified at community, regional, state, and national levels. For most projects, citizen scientists contribute observations of fauna, flora, and habitat, though a few projects exist in astronomy, meteorology, and seismology. Citizen science in Australia is also rapidly diversifying into new domains (such as online) and disciplines (such as biomedical sciences).

Region and name	Description
Austria *Bürgerwissenschaft*	Citizen science has developed rapidly over the last 3–4 years in Austria. In 2014, the first Austrian online platform for citizen science projects (*Österreich forscht*, http://www.citizen-science.at) began to connect citizen science projects and actors to foster this method and to ensure quality. The platform is borne by citizen science project leaders, so it is independent from institutions. In parallel, a second platform (Centre for Citizen Science, http://www.zentrumfuercitizenscience.at) was developed at *Österreichischer Austauschdienst*.
Brazil *Ciência cidadã*	In Brazil, the Citizen Science Movement (*Movimento Ciência Cidadã*, website http://www.movimentocienciacidada.org) is an effort focused on democratising access to Brazilian scientific production on topics of social interest. Some examples of citizen science projects are Farmer–Experimenter Groups, the ForestWatchers Project, and Contribua.
Chile *Ciencia ciudadana*	Chile has a long-standing tradition of Participatory Action Research (*Investigación-Acción Participativa*), which became widespread during social movements of the 1960s and early 1970s. There is also a legacy of close collaboration with artisanal fishermen and small-scale farmers, using Traditional Ecological Knowledge (TEK), which has only recently been considered 'citizen science'.
China 公民科学 *or* 公众科学 *(Simplified Chinese),* 公民科學 *or* 公眾科學 *(Traditional Chinese)*	The term 'citizen science' is translated to 公众科学 or 公眾科學 in simplified Chinese or traditional Chinese, respectively. This translation is close to 'public science' in English. A more direct translation is 公民科学 or 公民科學 in simplified Chinese or traditional Chinese, respectively.
Estonia *Kodanikuteadus*	The collaboration of citizens and scientists has a long tradition in Estonia, with roots beginning with the Estonian Naturalists' Society, which was founded in 1853. However, the awareness and understanding of citizen science is still expanding in Estonian society. There are many parallel translations of the term citizen science: *Kodanikuteadus* translates to 'citizen science' and can be misunderstood as 'science about being citizen', which is rather formal; *harrastusteadus* translates to 'hobby or amateur science', *rahvateadus* translates to 'people science', and *huviteadus* translates to 'hobby or lay science'. There are no existing associations for Estonian citizen science practitioners and there is no common website.
Europe *Citizen science*	Citizen science in Europe is mainly represented by the activities of the European Citizen Science Association (ECSA), which is a non-profit association organised to encourage the growth of citizen science in Europe. It draws on 200 individual and organisational members from more than 28 countries across the European Union and beyond. Launched in 2013, ECSA has grown from an informal network of civic educators interested in citizen science into the reference network of citizen-science initiatives for Europe.
Germany *Bürgerwissenschaften*	Citizen science in Germany (http://www.citizen-science-germany.de/) has long been visible among prestigious local groups, but has rapidly increased in the past decade. The project GEWISS (*BürGEr schaffen WISSen*, literally translated as 'citizens create knowledge', is an initiative of different university and non-universitary organisations, funded by the German Ministry of Education and Research. GEWISS reflects, promotes, and supports citizen science in Germany. As of April 2018, the online platform buergerschaffenwissen.de lists 81 current German citizen science projects.

Region and name	Description
Ireland *Citizen science*	Citizen science in Ireland has grown in the last decade, but it is still a relatively unknown concept. Most of the citizen science projects that have taken place are localized, with few having the support needed to become national endeavors. The projects that do gain traction tend to be contributory, and are often led by environmental or biodiversity-focused organisations such as the Environmental Protection Agency, the National Biodiversity Data Centre, the Irish Wildlife Trust, and Science Gallery Dublin.
Italy *Citizen science*	Although citizen science in Italy has become more common in the last few years, it is not a widespread concept. Defining citizen science in Italy relies on first discovering the existing citizen science projects, and this is hindered from a lack of clear terminology for this field. However, the international citizen science movement has recently activated some citizen science projects at the local, regional, and national scales of Italy. In 2015, an informal group called Citizen Science Italy was formed with the purpose of sharing experiences and developing the concept of citizen science. Most members, however, are observers or simply interested in supporting the development of citizen science in Italy. Nevertheless, Italy is among the most represented countries (in number of members) in ECSA, demonstrating great interest and potential growth for this field in the future.
The Netherlands *Burgerwetenschap*	Dutch people are involved in a variety of citizen science projects, for example, air quality monitoring and noise monitoring and gas extraction-induced earthquakes. These projects are often bottom-up in origin. The term 'citizen science' is '*Burgerwetenschap*' in Dutch, but the English term is also widely used. Since 2016, the Dutch National Research Agenda (https://wetenschapsagenda.nl/national-science-agenda/?lang=en) presents 140 overarching scientific questions and is the result of a unique bottom-up initiative, driven by the general Dutch public and a vast number of organisations in the Netherlands.
Spain *Citizen science*	The context of citizen science in Spain is similar to other countries in Europe, except for the language used by contributors, which is mainly Spanish and Catalan, and to a lesser extent Euskera and Galician.
UK *Citizen science*	In the late 2000s, the term citizen science gained popularity as projects, such as OPAL, began to use the term. Many biological recording schemes rebranded themselves as citizen science, as use of the term caught on in the media. Most citizen science projects in the UK are contributory, but there are some examples of co-created projects, for example, the ExCites group at UCL, which emerged from participatory action research.
US *Citizen science*	Citizen science is widespread in the US, which has the highest percentage of members of the Citizen Science Association. However, citizen science activities are not particularly co-ordinated among host groups. One important and growing network is within US government agencies, which are co-ordinated through the Federal Community of Practice for Crowdsourcing and Citizen Science (CCS) and the formal Agency Co-ordinators. In an effort to expand and accelerate the role of crowdsourcing and citizen science in the US government, a collaborative group of agencies released the Federal Crowdsourcing and Citizen Science Toolkit (http://www.citizenscience.gov/) as a venue for finding, planning, and maintaining federal citizen science projects.

Region and name	Description
Zimbabwe *N/A*	Most scientific work done by citizens in Zimbabwe is currently undocumented and occurring at a grassroots level, though there is little evidence of its existence. This work is conducted on such topics as traditional medicine for people and livestock, wild fruit and plant processing and preservation, civic construction, art, and climatology. Because communities do not recognise that they are performing 'citizen science', there is no word in Shona for the activity (and likely not in the other national languages of Zimbabwe). Zimbabwe's low GDP is the main hindrance to formal scientific inquiry, so citizen science has potential to grow in the country as a way to generate information and solve problems.

Source: M.V. Eitzel et al.[19]

Key message

- The practices of citizens doing science and of scientists working together with citizens occurs in many different countries, in many different ways, predates the use of the term citizen scientist or citizen science and is on the increase around the world.

Citizen Science Policy

The US appears to be more advanced than any other nation or indeed the EU as a whole in policy supporting citizen science activities. As a result, citizen science is widespread in the US, which has the highest percentage of members of the Citizen Science Association.[20]

One important and growing network is within US government agencies. In September 2015, the White House hosted a forum on citizen science and crowdsourcing.[21] In this context, citizen science was described as encouraging "members of the public to voluntarily participate in the scientific process. Whether by asking questions, making observations, conducting experiments, collecting data, or developing low-cost technologies and open-source code, members of the public can help advance scientific knowledge and benefit society." In conjunction with the forum, the US Office of Science and Technology Policy (OSTP) announced two new actions to encourage and support the appropriate use of citizen science and crowdsourcing at Federal agencies:

1. The OSTP issued a memorandum entitled Addressing Societal and Scientific Challenges through Citizen Science and Crowdsourcing. This memo articulates principles that Federal agencies should embrace to derive the greatest value and impact from citizen science and crowdsourcing projects. The memo also directs agencies to take specific actions to advance citizen science and crowdsourcing, including designating an agency-specific coordinator for citizen science and crowdsourcing projects, and cataloguing citizen science and crowdsourcing projects that are open for public participation on a new, centralised website to be created by the General Services Administration: making it easy for people to find out about and join in these projects.

2. Fulfilling a commitment made in the 2013 Open Government National Action Plan, the US government released the first-ever Federal Crowdsourcing and Citizen Science Toolkit to help Federal agencies design, carry out, and manage citizen science and crowdsourcing projects. The toolkit, which was developed by OSTP in partnership with the Federal Community of Practice for Crowdsourcing and Citizen Science and GSA's Open Opportunities Program, reflects the input of more than 125 Federal employees from over 25 agencies on ideas, case studies, best management practices, and other lessons to facilitate the successful use of citizen science and crowdsourcing in a Federal context.

Citizenscience.gov[22] is an official government website designed to accelerate the use of crowdsourcing and citizen science across the US government. The site provides a portal to three key assets for federal practitioners: a searchable catalogue of federally supported citizen science projects, a toolkit to assist with designing and maintaining projects, and a gateway to a federal community of practice to share best practices. Its Federal Crowdsourcing and Citizen Science Catalogue currently lists 409 projects over 26 agencies. Its toolkit shows the basic process steps for planning, designing, and carrying out a crowdsourcing or citizen science project. It also presents case studies as models and provides a resource library.

Examples of practical support for citizen science from Federal agencies, companies, and others include:[23]

- The White House showcased that anyone can participate in citizen science by installing a new rain gauge in the First Lady's Kitchen Garden, and becoming part of the Community Collaborative Rain, Hail and Snow (CoCoRaHS) citizen-science network of over 20,000 active participants who serve as the largest source of daily precipitation data in the United States.

- Making use of Federal lands and parks, the US Fish and Wildlife Service and the National Exological Observatory Network's 'Project BudBurst' offered an online course to support citizen science at wildlife refuges.

- The President's 'Every Kid in a Park' Initiative worked with organisations and universities such as the Cornell Lab of Ornithology to enable tens of thousands of families and school groups to contribute citizen-science data from Federal lands during the 2015–2016 school year.

- Building on its ConnectED commitment to provide its software for free to all K-12 schools, and responding to the President's call to action, Esri released a free open crowdsourcing app designed to empower citizen science. Teachers, students, and youth groups can create their own projects and use this app in the field to report observations and explore them on a dynamic map.

- Arizona State University's Center for Engagement and Training in Science and Society, the Museum of Science Boston, Public Lab, and SciStarter created a Citizen Science Tool Library, to increase access for students, parents, and other adults to citizen science data collection tools.

Citizen science in Europe is mainly represented by the activities of the European Citizen Science Association (ECSA),[24] which is a non-profit association organised to encourage the growth of citizen science in Europe. It draws on individual and organisational members from across the European Union and beyond. Launched in 2013, ECSA has grown from an informal network of civic educators interested in citizen science into the reference network of citizen-science initiatives for Europe. In 2016, ECSA published 'Citizen Science as part of EU Policy Delivery-EU Directives'[25] for use in discussions with the European Commission in order that we may press for similar initiatives across the EU and Members States in view of the opportunity citizen science presents to support EU policy makers in the delivery of key policy objectives.

Of all EU member states, Germany is arguably most advanced in its citizen science policy. The German research and capacity building project 'Citizens create knowledge, knowledge creates citizens' (*Bürger schaffen Wissen, Wissen schafft Bürger* (GEWISS)) has elaborated the Green Paper 'Citizen Science Strategy 2020 for Germany'.[26] The project is funded by the ministry and has been carried out by a consortium of member institutes of the Helmholtz and Leibniz associations in co-operation with partners. The Green Paper introduces the current role of citizen science, identifies pertinent challenges and recommends a series of actions to foster citizen science in Germany.

Currently, citizen science is described by the European Commission under Open Science as "both an aim and enabler of open science. It can refer to citizens 'doing science', for example, through crowdsourcing. Or it can mean greater understanding of science by the public made possible through 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 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. The public is also engaging in policy-making through, for example, agenda-setting for research systems."[27]

An EU-wide survey on citizen science was conducted in 2016 to map citizen science activities currently taking place across Europe (Fig. 3). The survey was designed to provide a preliminary evidence base for the development of the open science monitor and inform the development of citizen science indicators for the future. The survey targeted both researchers who run citizen science projects and research funders and supporters of citizen science.

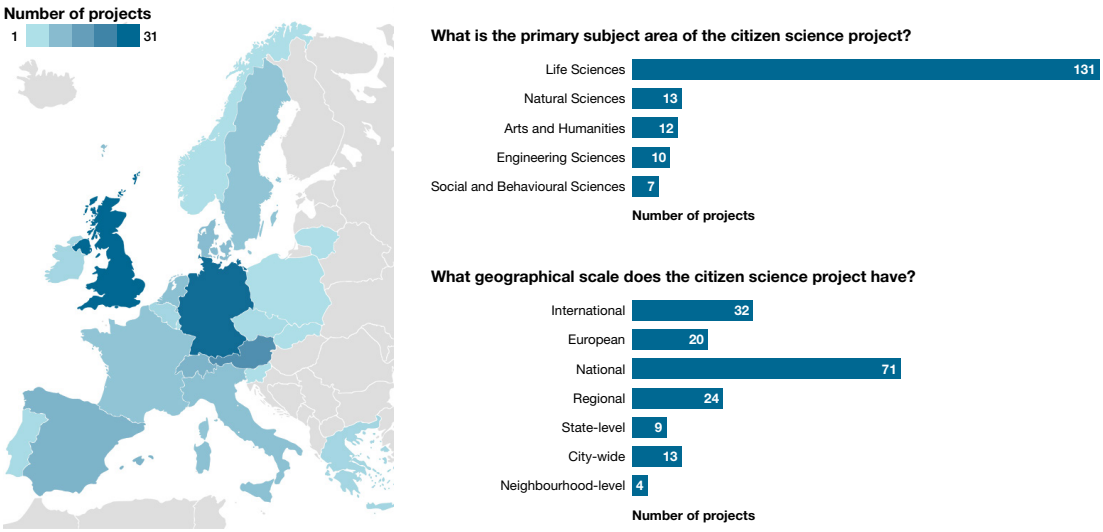

Figure 3 Map of citizen science activities taking place across Europe; field of study of the project; and geographical scale of the project based on an EU-wide survey on citizen science was conducted in 2016. Source: European Commission Open Science Monitor[27]

The projects were funded by different sources as shown in Figure 4. In terms of level of engagement, 87 projects were contributory (designed by professionals with public contribution of data), 47 were collaborative (designed by professionals with members of the public involved in contributing data, project design, analysis and results disseminate), 20 co-created, and 8 collegiate (run purely by citizens).

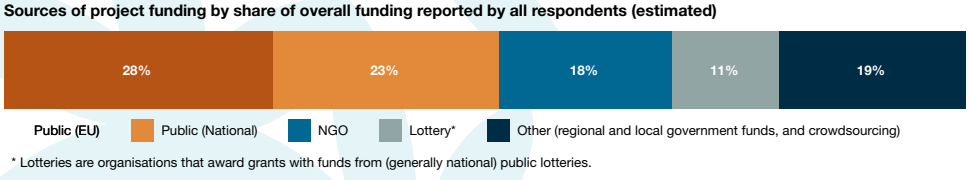

Figure 4 Funding of citizen science projects based on an EU-wide survey on citizen science was conducted in 2016. Source: European Commission Open Science Monitor.[27]

A Green Paper on citizen science published in 2013 by the European Commission's Digital Science Unit and Socientize.eu, defines citizen science as referring to "the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture. While adding value, volunteers acquire new learning and skills, and deeper understanding of the scientific work in an appealing way. As a result of this open, networked and trans-disciplinary scenario, science-society-policy interactions are improved leading to a more democratic research, based on evidence-informed decision making."[28]

The 2014 EU White Paper on Citizen Science[29] and the earlier In Depth Report on Environmental Citizen Science[30] both make the case that the time has arrived for a comprehensive review on the current use of citizen data by policy makers in the EU. Although there is no clear EU-wide policy on citizen science, the European Commission supports such projects. Examples from FP7 are listed in the next section.

In practice, the JRC is the part of the EC most active in the field of citizen science. It advocates that citizen science contributions have the highest chance to impact European policy and promotes citizen science in practical terms by providing the supporting scientific and technical services. For example:

1. It is investigating the setup of an archive of EU-funded Citizen Science projects. Descriptions of the projects and links to further details will be complemented with information about the produced research results, such as mobile applications and collected data sets.[31]

2. It initiated the development of a Citizen Science Platform[32] as a customisable tool to be used to launch data collection activities (including citizen science contribution) to extend the evidence base for European policies.

3. It uses citizen science approaches in its own research. For example 'The future of government 2030+' project focuses on a citizen-centric perspective on new government models.[33]

4. It organises meetings and trainings on citizen science or related topics to other organisations and individuals. For example, Citizen Science and Smart Cities Summit, February 2014.[34]

Key messages

- Citizen science is widespread in the US, which has the highest percentage of members of the Citizen Science Association. The US is relatively advanced in policy support of citizen science including within government agencies. Citizenscience.gov is an unequalled resource in terms of supporting citizen science in the US.

- The most coherent voice for citizen science in Europe is the European Citizen Science Association (ECSA). Its website (https://ecsa.citizen-science.net/documents) provides the best European-based collection of citizen science guidelines and publications.
- Of all EU member states, Germany is arguably most advanced in its citizen science policy.
- Citizen science is described by the European Commission under Open Science. It has commissioned White Papers, Green Papers, and In-depth reports on citizen science. In reality, the JRC of the EC 'practices' citizen science.
- A survey on EU-wide citizen science conducted in 2016 reveal the vast majority of projects participants located in the UK and Germany with most projects in the field of life sciences and most funding coming from national sources.

Examples of Citizen Science

Despite common accelerators, the implementation of citizen science unfolds differently in diverse corners of the world. In particular, the method and degree that citizen science is integrated into local, city, national, and international policy varies between towns, cities, states, countries, and continents.

Additionally, citizen science increasingly takes place on an international scale. Hence, it is impossible to define one or a few citizen science activities as examples of 'state of the art'. Instead this section gives examples of global, national and local projects, EU-funded citizen observatory projects and additional sources.

'Galaxy Zoo' (https://www.galaxyzoo.org/) is one of the best-recognised global citizen science projects. Launched in July 2007, it asks participants to participate in astronomy research by classifying images of galaxies online. Originally, the images came solely from the Sloan Digital Sky Survey, an astronomical survey covering a quarter of the sky and over 930,000 galaxies (SDSS, 2013). Now, images from the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS) are also used. Following publicity via BBC radio and the BBC website, tens of thousands of volunteers registered to take part within the first week and by April 2009, more than 100 million galaxy classifications had been. Each galaxy is classified by more than one volunteer, helping to increase confidence in the results. Tens of scientific papers have been published based on data from the Galaxy Zoo project. Volunteers have helped astronomers to make numerous discoveries, such as the first planet with four stars.

The 'Big Butterfly Count' (www.bigbutterflycount.org) is a national level citizen science project that takes place in the UK since 2010 between July and August each year and asks members of the public to get involved in monitoring butterfly populations in their area. Volunteers spend 15 minutes recording the numbers of butterflies they see in parks, school grounds, gardens, fields or forests. Butterfly Conservation, an NGO, provides an identification chart to help volunteers to recognise species of interest and they submit their results online via the project's website, or via a smartphone app (introduced in 2013). The project has several celebrity backers including Sir David Attenborough. Around 27,000 people took part in the 2012 survey, recording over 24,000 counts and more than 223,000 individual butterflies and moths from 21 target species. The results showed several species of butterfly declining by 50% or more since 2011, probably due to poor summer weather. Butterfly Conservation uses the data collected by volunteers across various schemes to assess the effectiveness of ongoing conservation work and direct its future conservation efforts. It also claims that data gathered in its monitoring schemes are used by the UK government to indicate the health of the environment.

An early example of local citizen science is that of Lake Kirkkojärvi near Kangsala in Finland.[35] It was recognised as an important habitat for birds and became part of the EU's Natura 2000 network of protected sites. However, the lake was in a poor condition due to eutrophication and unpleasant odours from algae, which were affecting local citizens. In 2002, the regional environmental authorities organised a public discussion event addressing the future of the lake. However, following the meeting it was concluded that no action could be taken due to lack of funding and the lake's

protected status. In 2004, local citizens became frustrated with the lack of action and contacted a local environmental official proposing to use an 'effective micro-organisms' (EM) solution to purify the water in the lake. The environmental official gave permission without informing the relevant authorities, assuming that the solution would be harmless but ineffective. The citizens' activity was then covered by local media, after which the regional environmental authorities banned further use of the EM solution in the lake. By 2006, the condition of the water in the lake had markedly improved, but the environmental authorities did not want to acknowledge any connection to the EM solution due to lack of scientific evidence, and offered alternative explanations. In media coverage, citizens were unconvinced by the authorities' explanations. Interviews with those involved suggest that the authorities felt they were bound to defend norms and regulations, and did not have the resources to nurture the growing interests and activities of local citizens. Citizens viewed the authorities as being inflexible and their expertise as questionable. The case demonstrates the potentially complex nature of interactions between citizens and local authorities.

There are already many examples of EU-funded citizen observatory projects:

- **CITCLOPS** (http://www.citclops.eu/) is a Citizens' Observatory for Coast and Ocean Optical Monitoring that aims to involve citizens in collecting data on seawater colour, transparency and fluorescence, using camera phones as sensors. The CITCLOPS Consortium includes academic institutes and technology centres in France, Germany, The Netherlands and Spain.

- **CITI-SENSE** (http://www.citi-sense.eu/) focused on air and noise pollution. The project aims to enable citizen participation in community decision-making and planning relating to these issues, through use of personal microsensors and mobile devices.

- **COBWEB**, the Citizen's Observatory WEB (https://cobwebproject.eu/), involved 13 partners (academic, industry, nonprofit, social enterprise and government) from five European countries. It explored the concept of 'people as sensors', using mobile technologies, and initially focusing on citizen involvement in environmental decision-making for the Welsh Dyfi Biosphere Reserve.

- **Eye on Earth** (www.eye-on-earth.net) is an online platform for sharing citizen observations and visualising data. Citizens can contribute observations on marine litter via the European Environment Agency's (EEA) Marine LitterWatch smartphone app, with the EEA aiming to assess the extent to which these data can be used to support beach litter monitoring under the Marine Strategy Framework Directive.

- **EVERYAWHERE** is a project that used low-cost sensors and social networking to collect data and opinions about the state of the environment. It is hoped that increased environmental awareness will improve environmental behaviour and act as a source of pressure on policymakers, as well as providing data to test the effectiveness of existing policies.

- **OMNISCIENTIS** (http://www.omniscientis.eu/) focused on local odour monitoring and mitigation project combining real-time measurement and citizen observations submitted through smartphones and tablets. Pilots are based at an Austrian pig-fattening farm and a Belgian industrial site.

- **WESENSEIT** (http://www.wesenseit.com/) was a project harnessing citizens' collective intelligence to develop a citizen observatory for water. Data was used as inputs for models to support planning, for instance, to prevent flooding. Partners hope to encourage communication between authorities and citizens, and active participation of citizens in decision-making.

- In addition, the flagship project **FuturICT** (https://futurict.inn.ac/) extended the concept of participatory computing – using volunteered computing power via a network – to exploit vast volumes of networked, location-specific information about the behaviour of citizens as data sources for its proposed Earth simulation platform.

For more examples, there are as many as a thousand active and searchable global citizen science projects listed on the SciStarter[36] website at any one time. Also the US Federal Crowdsourcing and Citizen Science Catalog lists over 400 projects across 26 agencies.[37]

Key message

- There are thousands of examples of citizen science projects: active, inactive and open for participation:
  - https://scistarter.com/
  - https://crowdsourcing-toolkit.sites.usa.gov/
  - https://en.wikipedia.org/wiki/List_of_citizen_science_projects
  - http://www.citsci.org/cwis438/Browse/Project/Project_List.php?WebSiteID=7

The Future of Citizen Science

Public perceptions

Public perceptions are likely to strongly influence the future of citizen science. Lewandowski et al. conducted a limited survey of public familiarity with, and perceptions of, citizen science.[38] They found that less than half of respondents were familiar with the term 'citizen science', but over 70% were familiar with the concept by another name. Most respondents were more confident in hypothetical citizen science findings when professional scientists were involved to some degree, compared to situations in which only citizen scientists were involved. Interestingly, 53% of respondents were confident in their ability to collect data and 31–47% confident with their ability to perform science process tasks.

Scientists' views

Getting more scientists engaged in citizen science is a key factor in advancing the field and creating significant impact on science and policy. While numerous studies have examined scientists' attitudes toward science communication, public understanding of science, and public engagement with science and technology initiatives, few studies have examined scientists' views in the context of citizen science. A study on the Open Air Laboratories (OPAL) by Riesch et al. examined scientists' attitudes toward citizen science directly.[39] The findings suggest that scientists involved in OPAL perceive public participation as a main component and goal of their project. Nevertheless, they question the ability of lay citizens to supply products of adequate scientific quality. A case study by Golumbic et al. examines how scientists perceived their commitment to the public, and it explores relationships between the ways that citizen science is defined and presented in the literature and the ideas that scientists in the case study have about citizen science.[40] The views voiced by the scientists in the case study regarding citizen science were divided into three main elements of citizen science – inclusion, contribution, and reciprocality as shown in Figure 5.

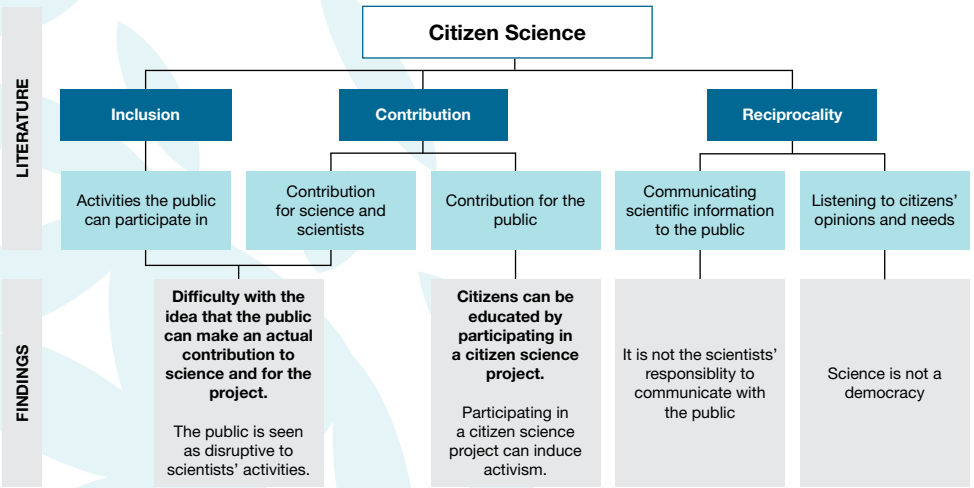

Figure 5 Citizen Science as viewed by the literature and the case study scientists. Themes with high consensus among scientists (eight or more) are presented in bold. Source: Golumbic et al.[40]

Overall, the study indicates that the scientists were motivated mostly by their interest in promoting scientific research and obtaining funding. Many of the scientists also found it difficult to accept the idea that the public can make actual contributions to science. Although the scientists acknowledged the advantages and benefits of citizen participation for the public, they had no desire to actively engage with the public and would rather conduct a traditional study without the public's involvement. Exposing scientists to public engagement and citizen science concepts, especially at early stages of their scientific carrier, could help overcome barriers and encourage scientists to further engage the public in such initiatives.

Trends and emerging technologies

The internet and geographic information systems and web applications allow participants to collect location-based data and submit them electronically to centralised databases. The ubiquity of smartphones, the potential for digital photo validation of questionable observations and the development of infrastructure for creating simple online data-entry systems provide added potential for initiating projects quickly, inexpensively, and with stringent criteria to ensure data accuracy. Table C lists a selection of projects and websites that provide cyberinfrastructure, tools, and information for project developers and participants.

Table C A selection of projects and websites that provide cyberinfrastructure, tools, and information for project developers and participants

Websites	Description	Resources
Citizen Science Central www.citizenscience.org	Provides support and aggregates resources for project developers, participants, practitioners, educators, researchers, information technology specialists, and evaluators	Toolkit for project development, tips and tools, reference database, conference proceedings, searchable project list, discussion forum, news feed, professional network
CitSci.org www.citsci.org	Supports the cyberinfrastructure and data management needs of citizen-science projects in a way that allows many users to create their own interface	Tools for creating customized data-entry forms so that volunteers can submit data
Data Observation Network for Earth www.dataone.org	Offers cyberinfrastructure and management structure to ensure preservation and access to multi-scale, multi-discipline, and multi-national science data, including citizen-science data	Educational tools on data management and National Science Foundation data plan requirements, data standards that will enable the integration of data from diverse studies and taxa, data analysis and visualisation tools
The Public Laboratory for Open Technology and Science www.publiclaboratory.org	Represents an online community that develops and applies open-source tools to environmental exploration, providing participants with inexpensive and accessible 'do-it-yourself' tools and techniques	Tools and methods, information on conferences

Websites	Description	Resources
SciStarter www.scistarter.com	Aggregates information, videos, and blogs about citizen-science projects; allows researchers access to 'community of doers' through targeted marketing of participation opportunities	Project finder and add project tools, editor's picks, member and site blogs
Volunteer Water Quality Monitoring www.uwex.edu/ces/csreesvolmon/	Supports expansion and increases in the capacity of existing Extension Volunteer Monitoring Network; supports development of new programmes	Aggregates information and support materials for water-quality monitoring across the US

These same tools are broadening the participation of non-scientists in science by allowing for the creation of community-based projects that arise out of local, practical issues or needs. Although it is too soon to assess the impact of this broadening, such empowerment means that resource management decisions, and the data that drive them, are increasingly in the hands of the people who will be affected by the outcomes. Currently, the contributory model of citizen science has been the most productive in terms of generating peer-reviewed publications, whereas collaborative and co-created approaches often have other, more practical goals. On the other hand, the impacts of collaborative and co-created projects have the potential to extend the influence of citizen science much further.

Newman et al. have recently examined the future of citizen science in terms of its research processes, program and participant cultures, and scientific communities.[41] In Figure 6, the authors summarise the key research process steps typically followed by citizen-science programs and aspects of program/participant cultures as seen in the past, present, and future. They foresee networked, open science and the use of online computer/video gaming as important tools to engage non-traditional audiences, and offer recommendations to help prepare project managers for impending challenges.

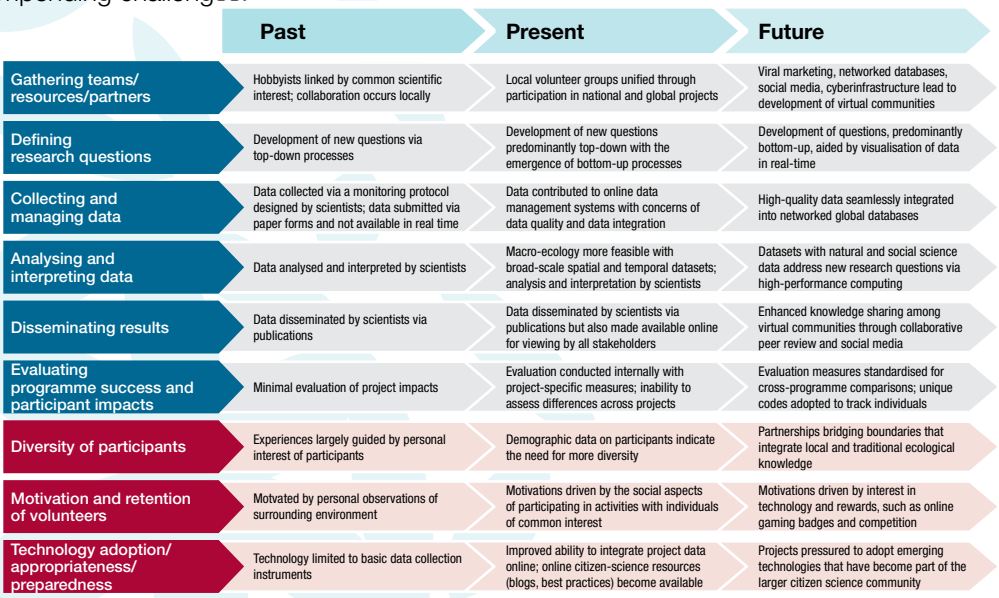

Figure 6 A summary diagram illustrating key research process steps typically followed by citizen-science programs and aspects of program/participant cultures as seen in the past, present, and future. Source: Newman et al.[41]

Whether contributory, collaborative, or co-created, citizen-science projects are a natural fit for science with public-policy implications because they engage the affected populations from the start. Built upon the assumption that participation in scientific research creates authentic learning experiences, citizen science is also a powerful way to generate public understanding of and support for science. In combining research with public education, citizen science addresses broader societal impacts by engaging members of the public in research at various stages in the scientific process and using modern communications tools of participation. And although citizen science projects face many issues, such as prioritisation, peer review, intellectual property rights and sustainable funding, a more formalised approach is emerging with networked organisations, associations, journals, and cyberinfrastructure that will help to address those issues.

Key messages

- The general public support citizen science but are more confident in science findings from professional scientists.
- When scientists collaborate with citizens, they are motivated mostly by their interest in promoting research and obtaining funding as opposed to a desire to engage with the public.
- Citizen Science is a developing tool for expanding scientific literacy.
- Future projects will be increasingly networked using open science and online computer/video gaming as important tools to engage non-traditional audiences.
- A more formalised approach of citizen science is emerging with networked organisations, associations, journals, and cyberinfrastructure that will help address issues such as prioritisation, peer-review, intellectual property rights and sustainable funding.

Ten Principles of Citizen Science

The future of citizen science is probably most accurately forecast by considering the key principles of citizen science developed by the 'Sharing best practice and building capacity' working group of the European Citizen Science Association, led by the Natural History Museum London with input from many members of the Association.[42]

1. Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding. Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.

2. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions or environmental policy.

3. Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence, e.g. to address local, national and international issues, and through that, the potential to influence policy.

4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.

5. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes are.

6. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for. However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science.

7. Citizen science project data and meta-data are made publicly available and where possible, results are published in an open access format. Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this.

8. Citizen scientists are acknowledged in project results and publications.

9. Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.

10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.

Selected Further Information

- Science in Seconds – Citizen Science, 2012: https://www.youtube.com/watch?time_continue=15&v=-OxO0eOnntE

- This Thing Called Science Part 6: Citizen Science, 2013: https://www.youtube.com/watch?v=N6eN3Pll4U8

- Citizen Science and Scientific Citizenship: same words, different meanings? Talk by Alan Irwin at the Joint Research Centre as part of the STS 'Contro Corrente' series of seminars. 15 October 2015: https://www.youtube.com/watch?v=Grhawx5TeBc

- Best Practices For Managing Intellectual Property Rights In Citizen Science, A Guide For Researchers And Citizen Scientists, T. Scassa and H. Chung, Commons Lab, Science and Technology Innovation Program, Woodrow Wilson International Center for Scholars: https://www.wilsoncenter.org/sites/default/files/research_brief_guide_for_researchers.pdf

- Crowdsourcing, Citizen Science, And The Law: Legal Issues Affecting Federal Agencies, R. Gellman, Commons Lab, Science and Technology Innovation Program, Woodrow Wilson International Center for Scholars: https://www.wilsoncenter.org/sites/default/files/STIP_CS_Legal_FINAL.pdf

- The role of citizens in the future of science, a workshop co-organised by STOA, the Swiss Centre for Technology Assessment (TA-SWISS, STOA's Swiss counterpart), the Mission of Switzerland to the EU, and SwissCore (May 19, 2017). The event focused on how citizen engagement can help us to respond to key opportunities and challenges in the next EU Framework Programme for Research and Innovation (Horizon Europe), which will succeed the current Horizon 2020 programme. For more details, see: https://epthinktank.eu/2017/05/19/the-role-of-citizens-in-the-future-of-science/

- In the framework of its Enlargement and Integration Action, JRC organised in collaboration with the Ministry of Civil Affairs of Bosnia and Herzegovina the 'Training on citizen engagement in Policy relevant Science, Technology and Innovation', in Sarajevo on 12–13 October 2017. For more details, see: https://ec.europa.eu/jrc/en/event/training-course/training-citizen-engagement-policy-relevant-science-technology-and-innovation

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