Embedding Citizen Science in Research: Forms of engagement, scientific output and values for science, policy and society

By¹ Dick Kasperowski, Christopher Kullenberg, Åsa Mäkitalo

University of Gothenburg²

Executive Summary

This paper addresses emerging forms of Citizen Science (Citizen Science), and discusses their value for science, policy and society. It clarifies how the term Citizen Science is used and identifies different forms of Citizen Science. This is important, since with blurred distinctions there is a risk of both overrating and underestimating the value of Citizen Science and of misinterpreting what makes a significant contribution to scientific endeavour.

The paper identifies three main forms of citizen science 1) Citizen Science as a research method, aiming for scientific output, 2) Citizen Science as public engagement, aiming to establish legitimacy for science and science policy in society, and, 3) Citizen Science as civic mobilization, aiming for legal or political influence in relation to specific issues. In terms of scientific output, the first form of Citizen Science exceeds the others in terms of scientific peer-reviewed articles. These projects build on strict protocols and rules for participation and rely on mass inclusion to secure the quality of contributions. Volunteers are invited to pursue very delimited tasks, defined by the scientists.

The value of the three distinct forms of Citizen Science –for science, for policy and for society, is discussed to situate Citizen Science in relation to current policy initiatives in Europe and in the US. In quantitative terms the US, and particularly the NSF have so far taken a lead in allocating research funding to Citizen Science projects (primarily of the first form), however, the White House has recently issued a memorandum addressing societal and scientific challenges through citizen science covering all three forms discussed in this paper. As Citizen Science is currently being launched as a way to change the very landscape of science, important gaps in research are identified and policy recommendations are provided, in order for policy makers to be able to assess and anticipate the value of different forms of Citizen Science with regard to future research policy.

¹E-mail: firstname.lastname@gu.se

²Draft policy recommendation paper, open for comments.

Introduction

It has become increasingly popular to engage masses of volunteers in scientific activities through open calls for assistance in some part of the scientific process³. The potential for volunteer contributions have expanded with the emergence of mass data and the possibilities of contemporary digital networking. Quite recently, two international organizations, the European Citizen Science Association and the US-based Citizen Science Association have been established to promote and organize further development of citizen science initiatives⁴. By extending research teams with online workforces of volunteers, time-consuming tasks that cannot be automated with sufficient quality (such as observation and classification) are possible to pursue effectively and cheaply. Such possibilities particularly respond to the needs of research fields with long-standing issues to cover large geographical areas or longer time-spans.

The discussion of the contribution of this form of collaboration between scientists and volunteers, referred to as citizen science, are hampered by the diversity of activities and projects to which this label has been applied. Volunteers that contribute to some part of scientific production, is but one use of this term. There are at least two other uses of the terms citizen science; one that concerns engaging the public to understand the role of science in society to make them better informed for decision-making. Another relates to ‘bottom-up’ activities initiated by citizens themselves who create scientific data in order to gain influence over problems affecting them and their community. We will discuss these three uses of the term citizen science and clarify their differences. This is important since in recent years the term “citizen science” has gained salience in European research policy⁵, here formulated in the 2014 White Paper on Citizen Science in Europe:

In Citizen Science, a broad network of people collaborate. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture. While they add value, volunteers acquire new learning and skills and gain a deeper understanding of the scientific work in appealing ways. As a result of this open, networked and transdisciplinary scenario, science-society-policy interactions are improved, leading in turn to a more democratic research based on evidence and informed decision-making.

In this description of citizen science several formulations need to be unpacked and qualified⁶, particularly the new learning and skills that are claimed to be acquired by

³See for example <http://zooniverse.org>, <http://ebird.org>, <http://fold.it>, and <http://citizensocialscience.org.uk/>

⁴See <http://ecsa.biodiv.naturkundemuseum-berlin.de/> and <http://citizenscienceassociation.org/> respectively.

⁵It was initiated through the SOCIENTIZE Project to the European Commission’s Digital Science Unit.

⁶In the 2015 report, validating the results of the public consultations on Science 2.0: Science in

citizens, and furthermore, if inclusion in scientific work necessarily leads to a more democratic form of research.

The main purpose of this Opinion Paper is to identify and clarify three forms of citizen science, to discuss in what ways the ambitious aims expressed on a policy level⁷ (for example, as above) can be related to current engagements of volunteers in scientific research, and to provide a set of recommendations for initiating citizen science projects as part of research funding schemes. Three concerns have been taken into consideration for this purpose: 1) the history and value of volunteer contributions to scientific work with generating or classifying data, 2) the different functions of volunteer contributions, 3) scientific output, and quality⁸. The paper discusses the values of the three forms of citizen science identified; for society, for policy and for research, and ends with a set of recommendations for policy makers and research funders.

2. Three forms of citizen science

2.1. Citizen science a research method

Scientific work has always relied on several actors, technologies and different forms of cooperation⁹. The engagement of volunteers as part of the scientific research process (citizen science as a method), has evolved into its current shape during the post-world war II period. In terms of scientific output, the traces are possible to follow back to the mid-1960s, notably with the North American Breeding Bird Survey. There are notable difficulties in assessing the scientific contribution of citizen science projects due to whether volunteers have been made visible or invisible in the publication of scientific results (Cooper et al. 2014) (see fig. 1 below). This must accordingly be taken in to account when analysing available data of scientific production from these projects.

Citizen science as a research method is significant for the broader discussion around the contribution to science and knowledge. In this form of citizen science, volunteers are invited and relied upon for particular tasks. Data collection (typically in the form of observation) and analysis (in the form of classification), have been a costly and often

Transition, the need to clarify the role of citizen science in research has recently been identified as an issue to address.

⁷See for example Nascimento et al. (2014), Holocher-Ertl et al. (2013), Pocock et al. (2014), <http://www.buergerschaffenwissen.de/>

⁸These areas of inquiry are currently addressed in an ongoing trans-disciplinary research project “Taking Science to the Crowd: Researchers, Programmers and Volunteer Contributors Transforming Science Online” based at the University of Gothenburg, funded by the Marianne and Marcus Wallenberg Foundation MMW 2013.00.20.

⁹Volunteer contribution to scientific fields such as for instance astronomy, has a documented history, see Kärnfelt, 2014, for an early example. Galaxy Zoo would be a current equivalent, with online volunteers assisting in the morphological classification of galaxies, mainly from the Sloan Digital Sky Survey.

Figure 1: Cumulative growth of Citizen Science publications. N = 1935. Search was conducted 2015-12-17. From Kullenberg & Kasperowski (2016).

time-consuming task for research in fields such as for example ornithology, ecology or astronomy. Today the access to data is no longer such a prominent concern per se due to technical developments, and some part of the scientific work can sometimes be automated. However, to many research fields, including social sciences and the humanities, ‘big data’ carry great potential for new discoveries and pending resources can be adequately used in ways that provide for such analysis to be conducted¹⁰. Typically volunteers are deployed to solve problems that cannot be automated, for example recognizing patterns in large datasets, conducting extensive fieldwork outdoors or providing a low-cost but high-quality input to a particular element in the research process.

An important concern and issue to address is of course data quality. Relying on contributions of volunteers, who have not undergone years of scientific training, has been a cause for lengthy discussion. Reliable contributions can, however, be made in specific types of projects with developed protocols that delimit participation to a set of well-defined tasks. Data quality can be both attained and controlled, particularly in citizen science projects that are conducted in digital environments

When people are called upon to solve some task, scientists carefully design standardised protocols in order to ensure that the volunteers involved in their projects pursue their task precisely in response to the needs of the scientists. One example is the use of protocols developed for observations, (which make use of the inherent ability of human perception to recognise patterns or movement in a large data set). This is the case in

¹⁰See Cohn, 2008, Silvertown, 2009, Delaney et al. 2008. For ongoing examples in the humanities, see for example <http://www.ancientlives.org/> and <http://www.operationwardiary.org/>.

the E-bird project based at the Cornell Laboratory of Ornithology, where citizens are invited to submit observations of changing patterns of bird migration¹¹.

Also when volunteers are engaged to classify available data, scientists develop, test and validate standardised protocols with guidelines, procedures and available choices. The clearest case of a project working along these lines is Galaxy Zoo, where volunteers contribute with classification of galaxies on an online platform¹².

Other ways to enable quality volunteer contributions is sometimes referred to as gamification, where the critical set of research premises for solving a task are embedded in the rules for playing the game. Notable examples include Foldit¹³, where the participants contribute by playing a computer game that solves complex mathematical problems inherent in protein folding.

A critical change for all these volunteer contributions to science, is the current element of digital networking and the possibilities of inviting masses of volunteers. This allows researchers to control how contributions are distributed among the mobilized. The design choices made as projects are developed, can to a larger extent build on the successes and failures of earlier generations of such research. The success of projects of this kind, and the protocols on which they rely, have encouraged a better visibility of volunteer contributions¹⁴.

To conclude, the main goal of these projects is neither to contribute to learning among citizens nor to democracy; rather the projects are targeted to crowds pursuing specific tasks, limited but important, to contribute to science.

- Scientific knowledge production is the main purpose of engaging masses of volunteer contributors.
- The quality of volunteer contributions to science (i.e. reported in scientific peer reviewed journals) is handled through scientific standards, protocols and procedures – as any research method.
- The tasks of volunteers are not dependent on their competence or experience (even though volunteers may indeed have tremendous expertise). Rather, the opposite is the case.
- That specific competences are not required does not mean that volunteers may not learn from participating. Whether they do learn, and by what means, is an empirical question.
- In these projects volunteers are not engaged as citizens in the classical meaning of term (i.e. as people with civil rights and duties), but rather as helpers to science.

¹¹<http://ebird.org>

¹²See <http://www.galaxyzoo.org>

¹³<http://fold.it/portal/>

¹⁴Delaney et al. 2008, Trumbull et al. 2000, Danielsen et al. 2005.

2.2. Citizen science as public engagement with science policy

While the first form of citizen science has as its main goal to contribute to executing delimited research tasks, the second form of citizen science is concerned with engaging the public as stakeholders in policy issues. This has been a longstanding concern, not only in terms of recruiting future generations to take an interest in and learn about science and research, but also to raise public awareness of scientific matters of concern to society. Since scientific activities might be associated with risks and hazards of consequence to society, this kind of initiative aims for a citizen that can act as a representative stakeholder of relevant interests at the intersection of science and society. Hence, there are issues where public engagement is considered an important concern, for instance, environmental problems and risks emerging from for example the proliferation of GMO, or the management of nuclear waste or fishery quotas, where scientific results may be contradictory and/or should be publicly deliberated for other reasons. Learning and understanding about science-in-society is accordingly a main concern for achieving this goal. This not only implies to learn about science and the critical component that any research incorporates, but also to master the relevant means to exert agency as a citizen in relation to the many socio- and techno-scientific issues that science generates. Public engagement in science is accordingly considered a long-term investment for research and for science to hold a prominent position in society.

Connected to citizen science as public engagement is the promotion of scientific literacy, often arranged as outreach projects; i.e. as pedagogical arrangements launched for instance in collaboration with schools, in after-school activities, with semiformal institutions like museums or science centres or in relation to recreational outdoor activities. Even though cases are rare, there are some projects that manage to combine both scientific data collection and scientific literature, one example is the Swedish Researcher's Night, where students ranging from pre-school to upper secondary school contribute with collecting data on seasonal variations and climate change while simultaneously discussing these issues in class¹⁵.

The central form of public engagement with science is arranged as stakeholder interactions with scientific experts and policy makers, around contested issues that bear on health, environment the right to livelihood and the management of common resources. Notable examples include the protection of the Baltic Sea ecosystem in connection with fisheries and fishing quotas where public engagement are suggested to improve EU's Common Fisheries Policy¹⁶. This form of citizen science is the one that has attracted the most attention of policy makers over the years because it supports the understanding that citizens can help identify and define relevant questions in the policy process.

While the main goal in engaging the public in this sense is quite clear, one must scrutinise whether such goals are actually reached by engaging volunteers in generating

¹⁵<http://forskarfredag.se/researchers-night/>

¹⁶See Linke & Bruckmeier 2015.

and classifying data (which is most often the case). What results participation in such activities yield in terms of whether and how actual engagement is reached, and what is learned, is a question that requires rigorous empirical study¹⁷.

- Public engagement with science concerns involving relevant stakeholders in contested science policy matters.
- The goal is to bridge the gap between scientific expert knowledge and lay knowledge to increase legitimacy and trust in decision-making.
- Volunteers are often called upon as citizens and learners (i.e. as people with civil rights and duties who should keep themselves informed). How citizens do learn about these matters, and engage in deliberations of concern for science and society, need to be thoroughly investigated.

2.3. Citizen science as civic mobilization

The third form of citizen science is first and foremost targeted to specific issues of concern. This form of citizen science is initiated by citizens themselves, who are triggered by a matter of concern for their community. The problems addressed accordingly originate outside of academic or other research institutions and, consequently, outside their main funding structures. The problems often relate to environmental issues of pollution, health hazards, species conservation, water and air quality or draining of natural resources. Typically scientific knowledge production per se is not aimed for, even though there are exceptions (i.e. scientific publications). The main objective instead consists of mobilizing the community in collecting data in order to provide evidence to launch legal processes or influence political decision-making. Even though these initiatives emerge from outside of the institutions of science, they heavily rely on scientific standards – and in many cases scientific laboratories – for validating data. The funding for these projects can be structured through NGOs or crowd-funding campaigns; sometimes in combination with funding for innovation of new science practices. These projects accordingly mobilize local communities by identifying a political or legal cause rather than contributing to science. Instead, the use of scientific data becomes a form of civic empowerment in relation to corporate or government interests. For example, the Louisiana Bucket Brigade has successfully launched several air quality monitoring projects to collect data on harmful emissions from local petrochemical industries, to promote regulation and policy decisions¹⁸. This third form of citizen science, has been studied by social scientists only in a few cases (Kullenberg 2015, Ottinger 2010, Wylie et al., 2014, Orta-Martínez & Finer 2010) and in the context of the research policy discussion around the ‘democratisation’ of research it is important to continue this type of social science research to better understand civic mobilization, also in relation to how societal institution might collaborate with such initiatives for creating sustainable and

¹⁷See Irwin 1995, Wynne 1992, Hagendijk & Irwin 2006, Callon & Rabeharisoa 2003

¹⁸See <http://labucketbrigade.org>

responsible forms of governance¹⁹.

- The aim of these projects is to gain political or legal influence in matters of concern to a particular community.
- Scientific data is produced and disseminated by volunteers, but these data do not serve conventional scientific purposes, such as advancing scientific knowledge or publishing in peer-reviewed journals.
- For science, projects of this kind generate data relying on scientific standards in the form of observations that might be of interest in new contexts of research, if the data and the protocols on which they rely, are open for use.
- The communities involved are, however, not likely to consider themselves as contributors to science.
- Projects like these will most likely gain momentum and importance, as current forms of digital networking provide possibilities to both generate and share data and protocols with others, potentially mobilizing ever larger communities to influence policy and decision-making.

3. Scientific output

There are several difficulties in assessing the scientific output of citizen science projects. The main reason for this complication originates in the fact that the term ‘citizen science’ has only circulated for a brief period of time, and is not even consistently used today. Thus, searching for scientific publications that is based on citizen science-related methodologies poses a challenge to any form of evaluation.

As seen in Figure 1, there has been a rapid growth in the number of publications containing the term citizen science over the past decade. But as discussed earlier such evidence suffers from the inconsistent use of the term in publications, if it is used at all. However, to get an idea of the contents of these publications in relation to what we have identified as the three forms of citizen science, keywords provide a first overview (see Figure 2). From this figure we can see that for example “climate change” and “public participation” link together the keyword “citizen science” with “public engagement”. Such volunteer participation seems mainly to be mobilised for monitoring in research areas concerned with climate change, biodiversity and conservation issues.

Furthermore this seems to be even more the case if we look at scientific output in relation to the projects involved (Figure 3). From the analysis it emerges that the projects recruiting volunteers to make observations and classifications of “birds and stars” have generated most of the scientific output. Also projects that use gamification (for example FoldIt) as a model for volunteer contributions have been successful in generating scientific output. The scientific value of generating and classifying large sets of data

¹⁹ See for example the US Environmental Protection Agency and their citizen science toolkit <http://www2.epa.gov/air-research/air-sensor-toolbox-citizen-scientists>

Name	Articles
North American Breeding Bird Survey	178
Galaxy Zoo	88
Common Birds Census	48
Cooperative Observer Program	34
Ebird	32
Nest Record Scheme	20
FoldIT	20
Wetland Bird Survey	17
Genographic Project	16
Planet Hunters	14
Globe at Night	13
Chicago Wilderness	11
North American Amphibian Monitoring Program	9
Evolution Megalab	7
Phytoplankton Monitoring Network	6
NestWatch	6

490 project names were searched in the WoS (For the entire search string and complete data, see [S2 Appendix](#)).

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Figure 3: Scientific output of citizen science projects, based on frequency of journal articles. From Kullenberg & Kasperowski (2016).

has proved successful in a number of projects. Keywords such as “public participation”, Figure 2, indicate the second form of public engagement and participation in science as studied by social scientists, albeit with a much lesser scientific output in terms of publications. We also note that the third form of citizen science is largely absent from this image, due to its low priority for achieving scientific output.

4. Values for science, society and policy: Clarifying aims and contributions

The three forms of citizen science initiatives, may all be of relevance for research policy, but have different main goals. The current overlap in terminology and at times persuasive rhetoric, points to the necessity of considering their differences in contributions to science. For the purpose of clarity we will discuss the three forms separately, addressing the value for science, society and policy respectively.

4.1. The value of citizen science as a method

This type of citizen science has its main value as a *scientific* enterprise. As defined in terms of volunteers helping science means that citizens have access only to a few

carefully selected steps in the research process. They are set to follow the participatory protocols for observation and classification. In most cases of large-scale citizen science projects, volunteers are absent in other steps in the research process. Formulating research questions, developing hypotheses, relating theory to data, analysing the results and publishing are still the tasks necessarily in the hands of professional scientists²⁰.

The democracy argument in citizen science is often treated as a function of inclusion. However, inclusion here pertains to volunteers who perform clearly delimited tasks defined by scientists. The volunteers involved, are by no means involved in activities or principles of representative democracy. In many contemporary accounts that promote citizen science as a method, inclusion and democracy are often confused, either deliberately in the form of strongly positive rhetoric or unintentionally due to conceptual opacity, as previously discussed.

It is thus imperative to evaluate citizen science projects and proposals with a strict distinction between on the one hand the scientific quality of data (which often relies on inclusion) and on the other hand the arguments in favour of democratising science, which relies on a very different notion of inclusion and citizenship. The positive effects of citizen science in society, in terms of possible synergy effects between (mass) inclusion as a vehicle for participation and democratisation, is an area which is currently under-researched by the social sciences and needs future critical evaluations.

Historically, the call for volunteer contributions to scientific work, has been most successful in the field of environmental monitoring; and lately astronomy stands out in terms of scientific output. All scientific disciplines that deal with similar types of observations or classifications of large amounts of data have, at least in principle, the potential to benefit from mobilizing masses of volunteers as a method. At least in projects building on pattern recognition and collection of species observations, the participatory protocols have proved to be sustainable and reliable. This potentially includes research initiatives in all disciplines. In the social and human sciences the scientific impact of citizen science as a method has so far been restricted due to its limited application. However, during the last few years a number of projects have been launched that may produce future impact.

As digital technologies and sensors become more ubiquitous and advanced, there is also an emerging possibility of individuals contributing and creating large sets of health-related data. Despite certain privacy and data security concerns, medical research will probably benefit from the current expansion of citizen science. In addition to conventional ethical issues in relation to medical research, we need to consider that citizens are not merely the objects of study, but also actively generate new data. The scientific value of generating and classifying large sets of data has been proved successful in a number of projects. Evaluations of the scientific value of citizen science should follow the same criteria as other forms of science; this value must not be compromised

²⁰For a discussion on responsible research and innovation (RRI), see www.rri-tools.eu.

by current and future possibilities of generating (big) data. Neither should scientific value be discriminated by ambitions of inclusion and democratisation.

4.2. Citizen science as public engagement with science policy

This form of citizen science has its main potential value as a provider of legitimacy and trust in science policy. Social scientific research on this form has shown that legitimate decision-making presupposes overcoming the gap between lay- and expert knowledge to achieve a deliberative and democratic process. However, research has also identified several obstacles, mainly in recognizing the problem of integrating local needs and knowledges with general policies and scientific knowledge. Social science on this form of citizen science has been very influential on a policy level, promoting discussions on the possibilities of democratisation of science. This form is, however, often confused or mistaken for the above-mentioned form, citizen science as a method. This has led to widely promoted expectations on citizen science, where citizen science as a research method has been amalgamated with citizen science as public engagement. If such interactions are possible is not supported by current research and most projects have clearly separated these two goals in practice. The argument that citizen science contributes to the democratisation of science, as frequently voiced on a policy level, must thus be qualified rather than being taken for granted.

4.3. Citizen science as civic mobilization

The main value of citizen science as civic mobilization lies in its possibility to combine aspects of the two previous forms of citizen science to strengthen the civil society. Citizen science projects of this third kind, initiated by citizens themselves, have therefore recently drawn the attention of social scientists and policy makers. Groups of concerned citizens have begun to use scientific methods and instruments to generate scientific data. It is initiated by non-scientists, is dependent on scientific laboratories and standards for measuring and evaluating collected data. Often the data that has been collected is sent to accredited laboratories for evaluation, since the citizens themselves have no access to such equipment.

While these practices rely heavily on access to standardised technologies for practicing citizen science, their lack of scientific output in terms of publications should not be confused with bad data. However, these volunteers do not consider themselves (and should not primarily be considered) as volunteer contributors to science. They are primarily engaged in generating scientific data for another type of cause, often political, or legal.

The future developments and consequences of this kind of *interested, mobilizing and data-driven projects* are hard to currently assess. They may pose several challenges

for science, for funders, but also for the very notion of citizenship. We know they will depend on an open and transparent development of technology, sensors and protocols for scientific classification and observation. In any case, such projects need to be both seriously considered and critically scrutinized.

5. Funding of citizen science projects

The funding of citizen science projects is difficult to assess with precision. The reasons for this are related to the absence of standardised procedures and mark-up practices for reporting funding in scientific literature in general. However, by analysing bibliometric data, it is possible to render visible the funding organisations of articles stemming from citizen science projects. It should be stressed, however, that these assessments are quite uncertain.

Citizen Science initiatives are currently supported by European and member state funding agencies. In quantitative terms, the US and especially the National Science Foundation takes the lead in allocating research funding to citizen science projects, see Figure 4-5 below.

Figure 4: Number of published articles sorted by funding country. 1997 - 2015, including both studies that use Citizen Science, CS, as a method or analyse CS as a phenomenon, then sorted by funding country. Note: EU here refers to projects funded directly by European Union funding agencies. Source: Thomson-Reuters Web of Science, search TS=“citizen science” conducted 2015-03-18, n = 629, Funding agency information retrieved from the FU field in when stated.

The projects supported by the National Science Foundation (NSF) primarily concern citizen science as a method, especially in the areas of biology, ecology and astronomy.

Figure 5: Number of published articles sorted by funding agencies 1997-2015. Source: Thomson-Reuters Web of Science, search TS=“citizen science” conducted 2015-03-18, n = 629, Funding agency information retrieved from the FU field when stated.

However, a recent memorandum by the White House has initiated funding that clearly extends to all forms of citizen science discussed in this paper. Thus, Federal Agencies are to include funding for citizen science in their budgets already for the fiscal year of 2017²¹. This policy initiative ties in with larger ambitions in the field of citizen science initiated by the US Citizen Science Association (in collaboration with its European and Australian counterparts) to standardize meta-data for all types of citizen science projects, creating interoperability and fusion of datasets generated²².

6. Knowledge gaps: where are we now and where next?

As a part of on-going scientific, technical and social innovations, the practice of citizen science creates hopes and expectations in research policy. Recent initiatives from the European Commission aim to change the very landscape of science, citizen participation and knowledge production in society. Several of the promises and challenges however, need to be turned into objects of research in their own right. General formulations (as for example in Science 2.0: Science in Transition), such as “bringing science closer to the public” or involving citizens for the “setting of research agendas”, need to be qualified in relation to the different forms of citizen science as discussed in this report. Especially, the SE Scientific Committee for Social Science find that the science-for-society argument in terms of empowerment and learning is largely taken for granted in both research and policy, and needs to be more thoroughly based on research that investigates the results

²¹See the recent White House memorandum "Addressing Societal and Scientific Challenges through Citizen Science and Crowdsourcing".

²²See <http://citizenscienceassociation.org/2015/11/12/introducing-the-data-and-metadata-working-group/>

and implications of citizen science projects in this regard. The most prominent gaps in research are:

- Policy research on the implications of implementing Citizen Science, as a general model for science (its impact on funding, regulations, the status of basic research etc.).
- General social science research on the degree, motivation, composition and quality of citizen science as civic mobilisation.
- Learning science research on the digital arrangements for collaboration with scientists, the learning processes involved and knowledge contributions of volunteers.
- Educational research on the implications and results of engaging formal or semi-formal educational institutions (schools, libraries, science centres, museums) in citizen science projects.
- Epistemological, historical and philosophical research on the consequences of data-driven research involving mass-observations that reshape the notions of certainty and uncertainty in scientific knowledge production involving non-scientists.
- The development for standards in meta-data for enabling data sharing between different citizen science projects, as a way of connecting all forms of citizen science and making data interoperable and analysable both inside and outside the domains scientific research.

7. Conclusion

The paper addressed the need to clarify some emerging forms of citizen science and to provide suggestion of how to distinguish between activities developed with the support of volunteers. The paper also meant to raise some issues and questions with regard to policy statements relative to the emergence of citizen science. More in depth research on the design, implementation and results of these projects is needed to help framing the discussions that must take place in the research policy debate.

8. Recommendations for research policy

The SE Scientific Committee of Social Sciences would like to invite policy makers to recognise that the notion of Citizen Science currently take on at least three disparate forms. In this respect, it is important first to clearly distinguish among their aims and contributions. It is particularly important for funding agencies to recognize the difference between citizen science as a method with the ambition to mobilize masses of volunteers and citizen science as public engagement that aims for stakeholder representation and capacity development. If these aims are confused, it will result in inappropriate evaluations for funding. Moreover, it is important to recognize the potential of citizen science as civic mobilization, as it will most likely play an important role in the future

as measurement technologies and internet connectivity increases, and as government institutions, especially in the US, increasingly have begun collaborating and supporting such initiatives.

This paper focuses on the following recommendations organised under 3 categories:

Funding

- No dedicated schemes are required, but specific calls for funding should have clear and relevant aims and projects should be assessed according to contributions in reaching these aims, whether these may be scientific, or deliberative and educational. It is the responsibility of the scientists designing proposals to define the quality assurance mechanisms to ensure that the output of these projects are of good scientific standards. In this way, funding agencies will consider these projects having same standards than any traditional scientific project.
- Citizen science projects where volunteers are invited as helpers to science present a complex structure and require funding structures that takes into account the complexity of their governance. Therefore, web based infrastructures, technical support and funding for a wider range of collaborations that do not necessarily fall under traditional academic staff, need to be taken into consideration as fundamental to the process of implementation of a given project.
- Citizen science as civic mobilization currently falls outside existing funding schemes since basic scientific advancements is not the goal of research. New funding frameworks and criteria for evaluation are necessary to support these types of initiatives, if supporting such projects is desired.

Evaluation

- Evaluations of the scientific value of these projects should follow the same criteria as other forms of science; this value must not be compromised by current and future possibilities of generating (big) data. Neither should scientific value be discriminated by ambitions of inclusion and democratisation.
- Attention should be paid to evaluation processes and criteria. Review panels need to be sufficiently broad to be able to evaluate the research design, disciplinary composition and necessary expertise. These panels should recruit the necessary expertise and competences appropriate for the type of project that is under evaluation or in the process of application. In most cases, this would require a multi-disciplinary composition of experts and well as reviewers with experience in citizen science and big data proposals.
- In addition to already recognized ethical issues, special attention should be directed to the visibility of and proper acknowledgement for volunteer contributions. Moreover, issues of privacy (especially in medical and social sciences research),

data protection and access to data should consider citizens not only as objects of study, but also as active co-producers of data and research.

Training

- The quality of protocols used in citizen science projects for observation and classification should be rigorously tested and the results of those tests should be reported to the scientific community to enhance transparency and quality of research methods and data.
- Open access to the development of infrastructural and instructional design (iterations of interface, web tools, classification standards, machine learning) should be encouraged, if compatible with ethical issues.
- Requirements of acknowledgements of the role of volunteers in the project in keywords or other searchable indicators should be specified.

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