CS TRACK
Investigating Citizen Science

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# Framework Conceptual Model

## D1.1

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| Executive summary | This deliverable contains a literature review of citizen science-related topics, situates citizen science in a historical context, discusses various conceptualisations of citizen science, and analyses existing categorisations and typologies of citizen science activities. It then presents a scheme of how citizen science can be categorised and characterised according to a broad range of relevant dimensions which can be used in Work Packages 2, 3 and 4, but also in future research, as no single endeavour may be able to take them all into account. Furthermore, it includes a short overview of the conceptual models for computer analytics that will be presented with all required detail in D1.2. |

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| | Citizen science activities, especially crowdsourcing, are nothing new, and so are not initiatives in public engagement in science. An introductory chapter puts citizen science into a historical context by critically analysing the claims some citizen science advocates make when referring to the origins of citizen science. Another chapter is dedicated to some prominent conceptualisations of citizen science, which are related to each other and critically assessed. The ongoing debates about terminology in citizen science and about defining citizen science in general are presented and their issues are analysed. Concepts of citizen science and terminology issues are closely linked to issues of typologies and categorisations. Since categorisations and typologies are elaborated to get an overview of what the various forms of citizen science, prominent categorisations and typologies of citizen science are critically evaluated in a chapter of its own.<br><br>The literature review addresses issues of actual, potential and claimed benefits brought by citizen science for the science system, ethical and integrity issues, caveats and potential pitfalls. Issues of participation in citizen science that are discussed in this report include participation patterns (as far as they are known), demographic and gender aspects, and barriers, enablers, incentives and disincentives for scientists and volunteers participating in citizen science. The chapter on education and citizen science discusses aspects of informal and formal, school and after-school, and online education. Furthermore, the visibility of citizen science activities and economic aspects of citizen science such as potential cost benefits, as they are presented in scientific literature, are assessed. The empirical basis for all this is relatively thin because not many systematic studies have been carried out.<br><br>To support Work Packages 2, 3 and 4, categorisations of citizen science activities were broken down into the Activities & Dimensions Grid of Citizen Science and a checklist for characteristics was developed that builds upon the explanation of citizen science in the Science with and for Society Work Programme 2018 - 2020. The chapter on conceptual models for computer analytics describes the role and context of computational analytics in CS Track, building blocks for computational representation and analytics, and the specific methods to be applied in Work Package 3. |

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# 1 Concept and rationale

*Michael Strähle & Christine Urban*

This report is Deliverable D1.1 of the research project CS Track which is funded by the European Commission under the Science with and for Society Work Programme. The aim of CS Track is to broaden the knowledge about citizen science and the impact citizen science activities can have. This overall objective is achieved by understanding and characterising citizen science activities so that one can say how they can be improved in terms of maximising their benefit for all participants and stakeholders, citizen and professional scientists, policymakers and funders, while meeting scientific standards of validity and reliability, paying attention to caveats and potential pitfalls, and respecting research integrity and ethics. The CS Track consortium investigates a large and diverse set of citizen science activities, discusses good practices and formulates knowledge-based policy recommendations in order to maximise the potential benefit of citizen science activities on individual citizens, organisations, and society at large.

What the term "citizen science" refers to depends, among other things, on science cultures, research orientations, fields of research and the kind of citizen participation in the respective research activities (Eitzel et al., 2017; Kullenberg et al., 2016; Riesch et al., 2013; Heigl & Dörler, 2017). As Eitzel et al. (2017) state: "In our collective experience with citizen science projects, no single term is appropriate for all contexts" (p. 1). Just to give a few examples: It can refer to crowdsourcing activities such as collecting weather data, to spotting animals in an online video, deciphering handwritten historic documents, solving scientific puzzles or making experiments in your garden, but also to formulating research questions and even to setting research agendas, developing robotic prototypes or conducting practical science projects in schools. The disagreement on what the term actually refers to, is puzzling. In 2014 a definition of citizen science was added to the Oxford Dictionary (OED, 2014) that narrows down its broader use. For the purpose of the Science with and for Society Work Programme the European Commission offers a description of citizen science that includes activities ranging from school education through citizen participation in scientist-led research projects to fab labs and citizen engagement in science policy. It is this broad use of the term "citizen science" that makes it difficult for experts, funders and policymakers to discuss its potential, caveats and strategies to maximise its benefit. Nevertheless, in the framework of CS Track the consortium uses the explanation of citizen science the European Commission gives in the Science with and for Society Work Programme 2018-2020:

> *(…) citizen science should be understood broadly, covering a range of different levels of participation, from raising public knowledge of science, encouraging citizens to participate in the scientific process by observing, gathering and processing data, right up to setting scientific agenda and co-designing and implementing science-related policies. It could also involve publication of results and teaching science.* (p. 41)

A second issue making it difficult to maximise its benefit is that, despite the hopes put into citizen science, there are only few systematic reviews of its benefit for scientific research, policymaking and education, which are limited to certain aspects such as data quality and fields such as marine conservation, particularly environmental sciences (e.g. Abourashed et al., 2021; Bedessem & Ruphy, 2020; Houllier et al., 2017;

Kankanamge et al., 2019; Kelly et al. 2020; König et al., 2021; Kelly et al., 2020; König et al., 2021; MacPhail & Colla, 2020; Mäkipää et al., 2020; Peter et al., 2019; Rathnayake et al., 2020; van de Gevel, 2020; Wolff, 2021; Young et al., 2019). Scientific literature on citizen science mostly consists of case studies, systematic reviews are scarce. From a perspective informed by the philosophy of science a general benefit for the sciences can be concluded (Elliot & Rosenberg, 2019). However, in other scientific literature this benefit is often only claimed - mostly in introductory remarks to case studies - but not elaborated and insufficiently demonstrated.

A literature search in Web of Science, Scopus, PubMed and Google Scholar shows that thousands of studies on citizen science projects have been conducted already. However, most of these are individual case studies; comparative studies aiming at a typology of citizen science projects are still scarce, studies aiming at a comparison across disciplines are even scarcer. Some efforts were made to develop a categorisation of citizen science projects. Generally, such typologies categorise citizen science activities into clusters of scientific disciplines (Kullenberg & Kasperovski, 2016), levels of engagement and types of activity (Haklay, 2015; Serrano Sanz et al., 2014), tasks performed by participants and overall project goals (Wiggins & Crowston, 2012; Wiggins & Crowston, 2011; Liu et al., 2017), and different strategies used to encourage volunteer contributions (Tinati et al., 2017; Reeves et al., 2017; Den Broeder et al., 2018). Other examples of comparative research on citizen science focus on the motivation for participation (Alender, 2016; Geoghegan et al., 2016; Jennett et al., Y, 2016; Rotman et al., 2012), quality criteria for citizen science and typologies of the different forms how citizens are involved in citizen science projects (e.g. Bonney et al 2009; ECSA 2015; Pettibone et al. 2016; Seymour & Haklay, 2017; Scheliga et al., 2016; Strähle & Urban 2017; University of Zurich 2015, Wiggins & Crowston, 2011) and science learning (Masters, 2016). Studies on citizen science projects rarely have a broad cross-disciplinary perspective; they mostly focus on a single discipline or a rather limited range of disciplines such as ecological research (e.g. Dickinson et al., 2010), ornithology (Bonney et al., 2009), geographic information research (e.g. Haklay, 2013), health research (e.g. Wright, Gardner, Roche, Unger & Ainlay, 2010), and history (Williams et al., 2014), but rarely on transdisciplinary research (Jahn, Bergmann & Keil, 2012). Accordingly, there is already a body of knowledge on participation patterns in citizen science, on various types of activities conducted, on challenges faced by citizen scientists, on enablers and barriers to participating in citizen science, on ways to attract citizens and on other important issues, however, mostly limited to research on specific citizen science projects, programmes and initiatives. An overview of the aforementioned issues across a broader range of citizen science projects is still missing.

In view of a body of literature that goes into thousands, the broad working definition and the dynamics of the field, this report can only offer a glimpse of the topics listed above, albeit a structured one. The authors hope that this report offers a concise presentation of the most important aspects of these topics and some new perspectives on the complexity of citizen science.

The Science with and for Society call topic under which CS Track received a grant, and particularly the rationale of CS Track, aim at an integrated investigation of participation patterns; societal, democratic and economic benefits of citizen science; incentives, disincentives, barriers and enablers to involving and engaging citizens and scientists in citizen science activities. Equal access and absence of discrimination are important desiderata for this endeavour. This brings in the questions of social conditions for access, gender equity, and world-wide accessibility. However, in current research on citizen science a broader geographical perspective, especially in respect to the global south, and a perspective on the gender dimension of citizen science are rare. Among other authors, Ordóñez Vela et al. (2017) remind us of the problems to transfer citizen science to social environments different from those in the global north where it originated without taking care of contexts. Otherwise, citizen and professional scientists may encounter new forms of scientific dependence, without contributing to the quality of life of those who carry out the studies. In the case of weather observation, other researchers raise the question whether citizen science is a male-dominated activity (Gharesifard et al., 2017; Endfield & Morris, 2012). CS Track addresses the issues of equity and accessibility regarding social conditions in a world-wide perspective. Especially, the consortium pays attention to them by investigating gender equity and gender distribution in citizen science activities and by investigating to what extent citizen science activities take gender and diversity issues into account.

The basic assumption is that for understanding citizen science and its benefits we have to understand how citizen science is conceptualised and what the different forms of citizen science are. For a further investigation of citizen science, it is necessary to categorise different citizen science activities according to the concrete tasks citizens fulfil and the roles they play, the (research) methods they use, the impact they may have (not) on the research objects and many more. Each type of activity needs separate assessment, because benefits, risks, barriers, enablers, need for specific training, ethical issues, etc. are likely to differ between - to give a few examples - investigation of the space, searching for rare butterflies or participating in online experiments. Specificities have to be related to gender, geographical and socio-economic differences.

The overall objective of Work Package 1, of which this report is a deliverable, is to investigate and consolidate the existing knowledge on citizen science by

- comparing and analysing various efforts that have already been made to categorise citizen science activities;
- identifying knowledge gaps, respectively open questions in relation to incentives, disincentives, barriers and enablers to the involvement of citizens and scientists; the types of activities conducted; participation patterns in citizen science; societal, democratic, economic and scientific benefits and potential caveats of citizen science;
- creating a conceptual framework for analytical tools and assessment procedures that consider the project objectives in relation to activities, size/ scale, funding, technical requirements (equipment) and visibility;
- generating basic conceptual models for analyses to be conducted in Work Package 3;
- and identifying exclusion criteria for the selection of citizen science activities that are further assessed in Work Package 2.

Moreover, Work Package 1 puts citizen science in EU Member States and Associated Countries into global and historical contexts.

For achieving the overall objective of Work Package 1 CS Track reviews scientific literature on citizen science, conducts expert interviews and analyses already existing ways/attempts to categorise citizen science activities. Based on this knowledge, this report categorizes citizen science activities in detail and analyses them in relation to the issues mentioned above. Such an understanding provides the basis for conceptual models to be applied in web analytics in Work Package 3. These models are generated from the categorisations.

The literature reviews presented in this report addresses a selection of topics listed in the aforementioned Science with and for Society call topic description. The respective reviews have been written by different authors. The topics are:

- Historical contexts
- Conceptualisations and definitions of citizen science
- Benefits, caveats, and ethical aspects of citizen science activities
- Participation patterns, demographical and gender aspects
- Enablers, barriers, incentives, disincentives for the mainly involved persons
- Educational aspects
- Visibility of citizen science activities
- Economical aspects
- Categorisations and typologies of citizen science

The reviews had the overall objectives

- to assess the state-of-the-art on what is known about these topics according to peer-reviewed scientific literature; and
- to identify knowledge gaps that could be filled in Work Packages 2, 3 and 4.

Since conceptualisations and categorisations of citizen science activities played an important role in developing CS Track's own categorisations of such activities, the research answered to the following questions:

- How is citizen science conceptualised?
- And what are the different forms of citizen science included in the conceptualisations, categorisations and definitions of citizen science?

***Structure of this report***

Chapter 2 of this report presents the methodologies the research for this report was based on. Altogether, this research consisted of desktop research. The literature analyses in chapters 3, 4 & 5 are based on a structured literature retrieval in scientific databases that is described in the methodology chapter. Chapter 2 further describes how the grid of citizen science activities and dimensions, the Activities & Dimensions Grid of Citizen Science, which is the basis for the conceptual models to be described in D1.2, was compiled and how categorisations and typologies of citizen science activities have been taken into account. Chapter 3 of this report puts citizen science into a historical context of amateur science and public engagement in science and research in democratic and authoritarian states. Chapter 4 of this report presents conceptualisations of citizen science and terminology issues in citizen science that are discussed among scholars. Section 5 of this report presents desktop research on benefits of citizen science: claimed, probable and proven ones. Ethical issues and caveats identified in scientific literature are discussed. The subsection on people in citizen science describes demographical aspects, presents findings on participation patterns and gender aspects, and discusses enablers, (dis)incentives and barriers for citizen science. The subsection on education aspects discusses citizen science in formal education, informal (science) education by citizen science and obstacles to conducting citizen science in education settings. The following short subsection discusses the online visibility of citizen science activities. Finally, chapter 5 concludes with a discussion of economic aspects in citizen science. Chapter 6 of this report describes typologies, classifications and categorisation that have been published in scientific literature and assesses their usefulness and limitations. In the subsections following these analyses, this subsection presents with all required detail the categorisations that provide the theoretical basis for the conceptual models for computer analytics in Work Package 3. Chapter 7 of this report presents the role and context of computational analytics in CS Track and the methods that will be applied for the analytics to be performed in Work Package 3. The literature analyses identified several knowledge gaps. Chapter 8 lists open research questions that are based on these knowledge gaps and relevant for Work Packages 2, 3, 4 and beyond. The report closes with concluding remarks (chapter 9) and an annex with notes on contributions (chapter 10) and a comprehensive list of all literature cited in this report (chapter 11).

# 2 Methodology

*Michael Strähle & Christine Urban*

**Literature review**

The literature review was mostly based on a systematic information retrieval in the Scopus, Google Scholar and PubMed databases by using keyword lists. These lists also included synonyms of keywords. When searching in databases, synonyms of keywords were added to the keywords with the Boolean operator OR when appropriate.

The main keyword that was always used was "citizen science" (in conjunction with "(participatory) environmental monitoring", "public engagement", "crowdsourcing", and "participatory research"). It was used in combination with "activities", "Africa", "Asia", "Australia", "barriers", "benefit(s)", "biodiversity", "categorisation", "categorization", "caveat(s)", "challenge(s)", "characteristics", "China", "conceptual framework", "cost(s)", "cost-benefit analysis", "definition", "democratisation", "democratization", "democratic", "economic benefit(s)", "economic aspects", "(science) education", "efficacy", "enablers", "ethics", "evaluation", "expectations", "funding", "gender (aspects)", "guidelines", "history", "impact", "incentives", "Japan", "Latin America", "lessons learned", "lessons learnt", "marketing", "motivations", "recommendations", "recruitment", "requirements", "research area(s)", "research integrity", "rewards", "risks", "roles", "RRI", "Russia", "science literacy", "(science) policy", "target group(s)", "tasks", "training", "typology", "USA".

The main part of the information retrieval took place from December 2019 - February 2020; information retrieval on some topics was repeated from October 2020 - January 2021.

In a first step, review authors searched for peer-reviewed scientific literature that is tagged with at least one of the keywords of the lists or contains it in the title or the abstract. To avoid a language bias by focusing only on literature written in English, the literature search also included publications in French, German, and Spanish. Literature formats included journal and conference papers, review papers, monographs, book chapters, scientific blog entries, and scientific reports. Also reports commissioned by public authorities and policy documents have been consulted if they are frequently cited in peer-reviewed literature.

In a second step, publications were selected by assessing their relevance and usefulness according to title and abstract but not according to frequency of citation. Of particular interest were empirical studies and meta-analyses. Except of the publication format, additional exclusion criteria were applied. Already at proposal stage it became clear that a considerable body of publications on citizen science consists of project presentations that do not discuss the topics of CS Track. These are scientific papers that present and discuss outcomes of scientific projects that made use of citizen science or what they considered as citizen science. If these publications did not include reflections on lessons learned from engaging with members of the public, they have not been selected. Also duplicate publications have been excluded from analyses.

In the chapter on the visibility of citizen science, so the authors, the selection of examples was guided by the aim to illustrate the described collaborations between citizen science and (social) media. For the chapter on informal science education in citizen science, so the authors, the referenced literature and project selection was guided by current discussions in the community and aiming to provide a well-rounded overview with illustrative examples from different countries and research areas for each ISE stakeholder area as identified by Falk et al. (2012).

After relevant research publications have been identified, the publications were coded with the respective search terms applying to them. In synopses of these publications common and controversial points were identified. Review papers and publications on citizen science were also analysed in respect to topics, scope, argumentations, claims, possible contradictions and sound conclusions.

### The Activities & Dimensions Grid of Citizen Science

To inform the qualitative research and the compilation of the project database in Work Package 2, the analytics tasks in Work Package 3 and the online survey in Work Package 4, a grid of citizen science activities and their dimensions was developed. Based on the Activities & Dimensions Grid of Citizen Science, among other things, conceptual models for the web analytics in Work Package 3 can be developed.

In a first step the authors searched for existing categorisations, typologies and conceptualisations which are (frequently) discussed in the scientific community and by citizen science advocates and practitioners. Of particular interest were meta-analyses of such categorisations and typologies and discussions about the feasibility of categorising, respectively classifying, citizen science. In a second step, the authors analysed different categories/types/characterisations of citizen science for their usefulness for CS Track's objectives and research questions. Because most categorisations were developed for theoretical discussion and not for empirical research, none of them could be applied in the original form. Empirical research requires that the issues to be researched can be operationalised and measured in some way, a criterion none of the categorisations met. Hence, the authors assessed the relevance of each category and type of these categorisations for the research objectives and questions of CS Track. This ended up with so many relevant aspects of categories and types that grouping them into categories proved practically infeasible. Dropping important details in order to construct some more general categories would not do justice to the multitude of possible characteristics of citizen science that other scholars considered as central traits and it would not suit rigorous empirical research. To allow for a sufficiently detailed differentiation between citizen science activities, it was decided to set up a grid of citizen science activities and important dimensions that could characterise them. Consequently, the authors broke down the categories into their elements. The Activities & Dimensions Grid of Citizen Science includes almost all citizen science activities and dimensions other scholars mention but in a more detailed form that makes manifestations of such activities and dimensions measurable.

In a next step the Activities & Dimensions Grid of Citizen Science was reviewed against additional categorisations (e.g. Franzoni & Sauermann, 2013) and meta-analyses of such categorisations (e.g. Schrögel & Kolleck, 2019) and refined.

Finally, the authors suggested some ways to operationalise the Activities & Dimensions Grid of Citizen Science by making the dimensions quantifiable. Operationalisations include measures that could be used to define minimum thresholds for some dimensions to determine if an activity should be considered as a form of citizen science at all.

The activities and dimensions were checked one by one against the different research issues CS Track aims to shed light on. In a further step, the citizen science activities and their dimensions were reviewed for their relevance for the research objectives and research questions of CS Track.

# 3 Historical context of citizen science

*Michael Strähle*

**A history of citizen science?**

The history of citizen science cannot be written for several reasons. First of all, the history of mathematics, history of philosophy, the history of sociology, and history of historical research can be written but not the history of citizen science. Citizen science is a label attached to quite diverse activities that cannot easily be labelled science: Science education, crowdsourcing, consulting citizens in matters of research by consensus conferences or similar public engagement schemes, interpreting data, even passive contributions by providing computing powers (e.g. SETI@Home) or gut samples have been called citizen science. (In Chapter 6 and 7 the authors present categorisations of such activities.) To write a history of citizen science, histories of all these activities would have to be written and put together.

Furthermore, there is no definition of citizen science all citizen science practitioners would agree on. Suggestions to make efforts to come to an agreement (Dörler et al., 2019) have not been widely accepted (e.g. Auerbach et al., 2019). On the contrary, efforts are made to attach the label citizen science to more activities that look like citizen science to those who apply it: to participatory environmental assessments, patient centred health research, the counting of locusts by peasants in ancient China about 2700 years ago (Irwin, 2018) (although these peasants probably did not consider themselves as citizens), to activities that seemingly remind of citizen science activities although those who conduct them may not consider them as scientific or, in some cases, themselves as citizens. Hence it is not a surprise that no monograph on the history of citizen science has been written. In Scopus, an abstract and citation database of peer-reviewed literature, the author could not find a single paper on the history of citizen science. What could be found are remarks on the history of citizen science, scattered across literature: in case studies on citizen science and conceptual papers, quite often in introductory remarks, and also in reports on citizen science that contextualise citizen science in the history of science. There is a book in preparation on the history of citizen science in Austria in the second half of the 19$^{th}$ century (Taschwer et al., 2019), however, this is quite an exception. And then there is considerable literature on the history of amateur science, the history of science education, and on public engagement in science; literature that does not refer to citizen science, let alone, to the history of citizen science. Therefore, this chapter is less about the history of citizen science but more about what is being told about the history of citizen science and how citizen science or the discourse on citizen science could be contextualised in a history of science, respectively a history or discourse on public engagement or public contributions to scientific research. Because this would warrant a larger research project of its own, this chapter highlights aspects of such a history.

One of the most comprehensive presentations of the historical context of citizen science is Strasser & Haklay (2018), which is part of a larger policy analysis that was commissioned by the Swiss Science Council, and Strasser et al. (2019). Because of its relative comprehensiveness, the following account is largely based on these two studies, enlarged by further literature, especially one touches upon contexts that have not been considered by those who wrote about the history of citizen science so far. When writing about the history of citizen science, one has to decide what is the perspective under which it is written. For instance, it can be a history of ideas, history of discoveries or a history of how it was shaped by social, political, institutional, and cultural contexts and how it shaped these contexts. Since, as already mentioned, such a task, under whatever perspective, would go beyond the scope of this chapter, the author follows the aforementioned studies to contextualise citizen science and critically scrutinise references citizen science proponents made to invent the origins of citizen science: to the history of citizen science and the giants on whose shoulders these proponents claim to be standing on.

**Confusing gentleman science with citizen science**

Strasser et al. (2019) mention historical precedents or origins of citizen science: amateur naturalists of the 18th and 19th century and the critique of science and its discontents in the late 1960s and early 1970s. The English version of the Wikipedia article on citizen science sees citizen science in the tradition of Isaac Newton, Georges-Louis Leclerc de Buffon, Benjamin Franklin and Charles Darwin. Ironically speaking, the authors could have added Albert Einstein who, aided by his wife Milena, developed his Special and General Theory of Relativity in his leisure time when he was an officer of the Patent Office of the City of Bern. It appears as if all gentlemen scientists of the 17th, 18th and 19th century were citizen scientists because they were "amateurs" which seems to indicate that "amateurs" are as capable as "professionals" to conduct scientific research, even on the level of Charles Darwin. This view is backed by referring to Paul K. Feyerabend and Erwin Chargaff, two outspoken critics of how scientific research is managed and governed and how it impacts on our societies. By this twist, citizen science is positioned as a kind of "counter-science", the true science, that is put in opposition to today's big science dominated by "money-biased technical bureaucrats" (Chargaff, cit. Wikipedia). By conducting amateur science or engaging members of the publics in citizen science, so can be concluded, citizen science reclaims the sciences back from the bureaucrats. This view is not convincing for at least three reasons. As Strasser & Haklay (2018) and Strasser et al. (2019) point out, "amateur" and "professional" are mutually exclusive categories that have not been established at the time of Newton, Franklin and Darwin. If they were amateurs, who were the professionals at that time? Secondly, irrespective how well justified and well-grounded all activities are that aim at engaging publics in scientific processes, technology assessment and science policy, the differentiation between the sciences and the public, the removal of the sciences from everyday life, was crucial for the development and the success of the sciences (Shapin, 1991; Michael, 1998). In the 17th century Paracelsans considered scientific research that is conducted removed from everyday life as defective since it is not related to and situated in the practical experience of artisans. Before scientific research became a full-time occupation, most scientists and scholars earned a living from other preoccupations. The famous 18th century experimental physicist Georg Christoph Lichtenberg was a university professor, however, astronomer Johannes Kepler earned a living as an astrologist. As Strasser & Haklay (2018) mentioned, Isaac Newton was Master of the Mint for the King in London. Interestingly, Newton considered his research in alchemy more important than the scientific discoveries he is famous for (Dobbs, 1991). The 17th century philosopher Baruch de Spinoza, who was a lens-grinder, a quite profitable profession at that time, and rejected an appointment as a professor of philosophy in Heidelberg, on the one hand embodied the knowledge growing out of practical experience the Paracelsans held in so high esteem, on the other hand he more or less secretly wrote at home most abstract, nevertheless revolutionary philosophy that reduced God to the laws of nature and the substance of the universe.

Thirdly, citizen science is already contributing to big science, big science already conducts citizen science. The most obvious example for this is CERN's CitizenCyberLab which has already engaged thousands of members of the publics in high energy physics, a research area that does not immediately come to one's mind if one thinks of public engagement in the sciences or of citizen science at all. One does not have to be too critical with a Wikipedia article because entries in Wikipedia can always be revised and improved. However, the increasing institutionalisation of citizen science through national and international citizen science associations like ECSA, CSA & ACSA raises the question why so little attention is paid to the historical context of citizen science. Moreover, the comparison with Darwin and Newton conceptualizes public participation in a way that puts expertise in its very centre (Strasser et al., 2019).

Strasser et al. (2019) point to another, more appropriate way how to conceptualise public participation in the sciences: domestic space. Much citizen science is taking place at home; people use their computers at home to fold proteins, for instance. "The home was, since the scientific revolution, the key place for the production of scientific knowledge, especially among natural philosophers developing experimental ways of knowing (…) in the domestic kitchen (Shapin, 1988)" (p. 58). The professionalisation of science is closely linked to the separation of spaces: spaces for living and spaces for working. Since science has become a profession and paid full-time occupation, the separation of the spaces where one lives and where one conduct research marks the difference between those who conduct scientific research as a profession and those who conduct it as a leisure time activity, at least in the experimental sciences. Some scientists may have become painfully aware of this separation of spaces during the lockdown's during the COVID-19 pandemic when they could not go to their laboratory or to libraries as they were used to. Conferences have been (at the time of writing they still are) held online only, without much informal space for exchanges with colleagues about potential funding, applications, etc. (How will this impact on the production of scientific knowledge?)

### Crowdsourcing has a long-standing tradition in Asia and Europe

Besides such individual contributions, in other fields of inquiry we can see practices one probably would categorise as crowdsourcing. One could even say that there is a long-standing tradition since centuries of involving volunteers, decoupled from the experimental sciences, in crowdsourcing empirical data. Crowdsourcing is and was not restricted to the Western hemisphere. In ancient China persons collected data on migrant locusts, in Japan citizens count cherry blossoms (Irwin, 2018), and in Africa pastoralists report environmental data in what is called participatory environmental monitoring, respectively participatory environmental assessment (e.g. Turreira-Garcia et al., 2018; FAO). At least beginning with the 17$^{th}$ century, in Europe "it was common for scientific institutions to collect observations from a vast range of people residing in different places" (Strasser & Haklay, p.38). This resulted in sometimes vast observer networks that spread beyond national borders. People collected – and still collect - weather data, identified and collected specimens of plants, reported seismic data, measured water levels, reported trout distributions in Spain (Clavera et al., 2014 & 2017) and observed animals, they keep archives of historical documents, write regional histories and even run museums, for instance museums of local history, which, among other things, display documents, photograph, paintings, and everyday objects which are important for the history of a specific district or region.

From the very beginning these cooperations and networks of contributors have been initiated by the most prestigious scientific institutions such as the Royal Society. Why? Because they relied on these networks. These networks became more and more professionalised by establishing standards and organisational structures to become less dependent and occasional contributions and to rely on systematic ones. Strasser & Haklay (2018) refer here to weather studies. Meteorological societies provided the instruments for measuring weather data and instructed naturalists how to record weather phenomena and measurements. Austria's oldest crowdsourcing project - PhenoWatch -, which is called a citizen science project today, collects weather data. It commenced in 1851 and is organised by Zentralanstalt für Meteorologie und Geodynamik. Meanwhile there is also a citizen science project on old weather data, called Old Weather. The project engages volunteers to transcribe historic ships logs from the 19th and early 20th centuries. Such data about past weather are vital for climate science and also for historical research. One could say that such networks of volunteers have always been important whenever a single person or organisation could not conduct this collection of data alone.

Such calls for contributions could even be recruitment measures. Academies organised competitions and awarded prices for providing scientific or technical answers to practical problems (Caradonna, 2012, cited according to Strasser & Haklay, 2018). The competitions were open to everybody, irrespective of qualifications or social rank.

This may indicate that at least in former times everybody, irrespective of qualifications and social rank, could contribute to the sciences, bluntly said: that everybody was or is an expert. However, this would be a quite romanticising picture of scientific endeavours. Crowdsourcing, the mobilisation of non-professional contributors to scientific research, is neither an "innocent" approach, nor does it necessarily contribute to the democratisation of the sciences. For example, weather forecasting served military campaigns (Strasser & Haklay, 2018). Telegraph networks made it possible to collect weather data from far distances. Nor are amateur science and crowdsourcing *per se* innocent practices that contribute to the democratisation of the sciences and democratisation at large.

### *Crowdsourcing in totalitarian states*

Under the rule of Mao Zedong, China promoted mass science, science by the masses, for instance in earthquake prediction (Fan, 2012). Since for orthodox Maoists scientific research was political, pervaded by western bourgeois or imperialist behaviour and thinking, it was imperative to bring the knowledge of the proletarian masses into the sciences to create a Chinese non-elitist science that makes China independent from western science. This led to an amalgamation of scientific knowledge with folk knowledge that yielded unreliable results.

To understand this policy, one has to understand how China – and also Japan - experienced western science and technology in the 19th century and reacted to it. China lost the Opium Wars because it had no appropriate answer to British weapon systems, especially the canons of the British Navy. The British surprise attacks on Chinese harbours and the humiliation of China that resulted from China's defeat first increased calls for a modernising of the Chinese Army by importing western weapon technologies, later calls for acquiring western science and technology and abandoning Chinese traditions in science and technology completely. As Japan, China was shocked by the capability of western weaponry. For critics of the late Qing dynasty, the resulting partly colonisation of China by western powers was a clear indication of the decadence of the Chinese elites. Since then, the reference to western sciences meant to save China through western science. This urge to take on western science prevented the critical appraisal of Chinese traditions of conducting research (Needham, 1979). Such an appraisal began under the rule of Mao Zedong, when Joseph Needham started it. Today the Chinese government supports Traditional Chinese Medicine (TCM) and western medicine alike. However, its support for TCM is disputed also in China (Zhu & Horst, 2019).

To give another example: The Soviet hut labs movement that started as a newspapers campaign in the 1920s (Aronova, 2017). Reminding a bit of science shops, a newspaper called peasants to direct questions to scientists. The newspaper served as an intermediary between scientists and peasants and published the scientists' answers. At the same time the intermediary encouraged the peasants to pursue experiments and create so-called "hut labs". After World War II the hut lab movement has grown to a network (Joravsky, 1970, cit. Aronova, 2017). "Many collective farms established meteorological stations and kept routine weather observations; for the most part, the hut labs were engaged in experimenting with crop rotation, fertilisation, weed control, and stimulation of seeds and plant growth (Anon., 1950; Chmora, 1949). However, the production of scientific results was *not* the aim of the movement. Rather, the hut labs were endorsed as a cheap and easy way to increase yields and exalted as a new way of doing science" (Aronova, 2017, p. 235). Lysenko, a biologist and agronomist, was director of the Institute of Genetics of the Academy of Sciences of the USSR. He favoured Lamarckism over Mendel's laws of biological inheritance and made it to a doctrine that theoretical biology must follow Soviet agricultural practice (Editors of Encyclopedia Britannica, 2021). For him the hut labs provided the evidence he was looking for, and he praised those who worked there as experts equal to professional scientists.

*Citizen seismology in the USSR and what it might say about today's citizen science*

Aronova (2017) also presents a case of citizen/civic/amateur seismologist in the USSR, the case of Vladimir Mannar. He detected a niche for himself in earthquake prediction (see for the following Aronova (2017), pp. 236-245). Similar to the citizen science projects CASTOR and OPAL which offered citizen scientists instructions for how to build low-tech sensors for measuring air quality, Mannar planned to publish a manual on how to build a low-tech seismic station. In Russia, involving volunteers in earthquake research dates back to the 19th century. According to Aronova (2017), staffing seismic stations with non-professionals was usual practice. The originality of Mannar's idea was to engage in earthquake prediction. Among villagers he collected observations of extraordinary events precursing earthquakes, trained pupils in making observations, designed instruments and, finally, the Geophysical Institute in Moscow appointed him as a technical supervisor of a seismological station. However, the acceptance of plate tectonics theory made earthquake prediction a big science enterprise which relies on statistical assessments and probabilities instead of observations, also in the USSR. Mannar called it a capitalist science. Because of changes in scientific theory and the role of high technology in seismology, a paradigm shift (Kuhn, 1962), Mannar's contributions were no longer needed.

With further advances in machine learning, this could also happen to some of today's citizen scientists who tag images of plants or animals, engage in taxonomy, and spot monkeys in videos. Citizen science activities would have provided the vast data amounts needed to train algorithms (Ceccaroni et al., 2019). As a consequence, citizen science tasks could become more demanding and require more training for citizen scientists. As a non-intended effect, the threshold for joining a citizen science activity could be higher than before because participation would require more expertise or time, thereby being more accessible to people with corresponding education and time resources (Strasser & Haklay, 2018). Another consequence could be that projects could have to allocate more resources for training participants, which could make projects less economically feasible.

### 19th century: The professionalisation of the sciences, with amateur ornithology that challenged professionals

Science became a more or less regulated profession by the 19th century. As for instance Strasser et al. (2019), Strasser & Haklay (2018) and Felt et al. (1995) mention, since then we can speak of professional and amateur scientists. This has to do with the increasing role of the sciences, especially the natural and technical sciences, for governments and industry. Especially in Germany governmental research institutions and higher education institutions were established; industry established its own research laboratories; universities were organised according to the research driven Humboldt model; and governmental funding of basic research was provided. The professionalisation of the sciences changed the relation between those who conducted research in the public; it also changed how scientific knowledge was communicated to society at large. Parallel to the economic rise of the bourgeoisie, the public sphere emerged (Habermas, 1990/1962). In the 18th century those who watched experiments in physics and chemistry in laboratories, or discussed new findings and theories in salons and cafés (Bensaude-Vincent, 2001), considered themselves as citizens of the republic of science. Diderot's and d'Alembert's Encyclopédie, probably the most important publication of the Enlightenment, which had the objective to present knowledge that was based on experience, empirical findings and reason instead of doctrine and dogma, was a success also in economic respects (Darnton, 1993). In the 19th century, with the professionalisation of the sciences, new printing technologies and increasing literacy, popular science magazines were established, which became a commercial success. Scientific discoveries became an item of mass consumption, not in cafés, cabinets or salons but at home (Bensaude-Vincent, 2001). At first sight, the spatial division between professional scientists and the publics on the one hand and the expanding popularisation of the sciences on the other might have kept out the publics from scientific endeavours. At the same time, British magazines encouraged readers to report inventions and scientific observations. In botany amateur scientists contributed to plant taxonomy. In Paris and Berlin fully equipped astronomical observatories were established, which were open to the general public and amateur astronomers (Bensaude-Vincent, 2001). In Germany the first so-called Naturvereine (natural history societies) were founded in which amateur scientists conducted scientific research on plants and animals. Mahr & Dickel (2019) analysed the relations of such a natural history society, the German Ornithological Society (Deutsche Ornithologie-Gesellschaft, DOG), with professional ornithology and how it compares to today's crowdsourcing practices. Established as a formal association, the members of the DOG set up their own research agendas and methods independently from professional ornithologists, who mostly turned up their nose at these endeavours. There was a striking difference in organisational structures, too. The DOG was organised as an association whose members have been elected and were accountable to the members of the DOG, which collaborated on an equal footing, while professional ornithology was hierarchically organised.

Apparently, the DOG differentiated itself from professionals by engaging not in taxonomy that can be conducted in an armchair but in field observations. What is more, the huge number of members dispersed across Germany allowed for research for which professional ornithologists would have to organise themselves as a network with a common research agenda: biogeographical research. Having founded its own journal (Journal für Ornithologie), the DOG organised large bird counting projects, following a standardised method which allowed statistical analysis, by publishing calls for contributions. Because of the success of these campaigns amateur and professional ornithologists in the United Kingdom, Austro-Hungary, and the United States adopted parts of the research design. As Mahr & Dickel (2019) put it in drastic terms: It was hijacked by experts (p. 11).

Today's information and communication technologies make crowdsourcing much easier. The smartphones we have in our pockets are powerful computers that, among other things, make it possible to take photographs of birds and plants and upload them to platforms such as iNaturalist or Zooniverse. No doubt, the internet and smartphones are game changers for citizen science. Compared to today's crowdsourcing projects, the amateurs at DOG set up their own research agenda, research design and research infrastructure. They organised themselves as peers and discussed their observations, whereas today's crowdsourcing consists of a transfer of data only. How these data are processed into scientific output is not always convincingly explained by project organisers, also coordinators and organisers are not tired of stressing the educational value of participating in their projects. Understanding how such uninvited participations (Wynne, 2007) as DOG's relate to and impact on science and technology could help us to create a more inclusive science system.

**20th century: Big science and its critics**

Beginning in the 1930s and continuing during the Cold War when big science came into being, division of labor in science and technology became more widespread, scientific institutions became professionally managed and received almost unlimited funding until the 1980s when expectations began that science and technology should contribute to economic competitiveness (Felt et al., 1995). This goes hand-in-hand with the rising importance of the experimental sciences (Strasser & Haklay, 2018) and modern physics (Bensaude-Vincent, 2001). In parallel the role of an invited participation in science and technology declined (Strasser & Haklay, 2018). Mahr & Dickel (2019) consider DIY biology[1] as uninvited participation in experimental sciences that challenges professional sciences. No doubt, DIY biology does not only challenge the norms and routines of professional biotechnology, it also raises ethical and integrity issues because it is less regulated than professional molecular biology.

First the dropping of atomic bombs on Hiroshima and Nagasaki, later, among other things, atomic energy, the toxic effects of DDT on the environment (Carson, 1962) and genetic engineering led to controversies about risks and adverse effects brought about by science and technology. Although these controversies may look like having

[1] Do-it-yourself biology is a movement grouped around the platform diybio.org that puts genetics into the hands of interested publics. The term refers to all kinds of experiments in genetics outside research labs that range from simple genetic modifications and bio art projects to experiments in body enhancements (Ireland, 2014).

originated outside the scientific communities, they have been stimulated by members of the scientific communities who addressed the publics to sound alarm on developments in the scientific communities they considered of tremendous public interest. Erwin Chargaff warned of threats by genetic engineering, Rachel Carson wrote a bestseller about the toxicity of DTT and the effects it has on the environment. Together with his wife, Linus Pauling organised the petition against nuclear weapon development that was signed by thousands of scientists, among them dozens of Nobel Prize winners, that had a tremendous impact: the ban of atmospheric testing of nuclear weapons and the limited test ban treaty (Strasser & Haklay, 2018). Additionally, in the 1960s also protests against the Vietnam war and the role of scientific research led to a questioning of the directions of science and technology and raised the issue of who actually benefits from them. In the 1960s a citizen scientist would have been a scientist acting as a responsible citizen. Today a citizen scientist is a citizen who contributes to scientific research without having to be a qualified researcher or scholar (Strasser & Haklay, 2018).

In the 1970s we can discern invited and uninvited public participation in scientific research. Uninvited participation means here contributions to scientific research that were neither initiated nor funded by research institutions or governmental research funders. Strasser & Haklay (2018) mention as examples of such public participation: women's health movements which, among other things, aimed at improving biomedical knowledge about women's health by self-examination; the Black Panthers, who initiated the only research projects on sickle cell anaemia, because they considered it as a neglected research topic in health research; the case of citizens of Woburn, especially mothers, who initiated a research project on toxic waste and who convinced professional scientists to support them; and finally the famous case of ActUp, an AIDS activist group, that, after overcoming resistance from the scientific communities was involved in scientific research and AIDS. (On the latter see also Epstein, 1996.)

Science shops are an example of what some STS scholars would call invited participation. They are contact points for public research requests. The first science shops established in the Netherlands, where they are called wetenschapswinkels. In English, "science shop" is an odd name as it insinuates that one can buy something there. In Dutch "winkel" and in German "Laden" have connotations of some organisation of the alternative movement and self-organisation and signal an institution with a low threshold to enter. The first Dutch science shops have been established at universities at natural science departments. Located at the departments or faculties or at the university level these science shops are contact points mainly for civil society organisations and interested citizens with some research demand. From the Netherlands, the idea of science shops spread around the world. Nowadays there are science shops in Austria, Germany, Denmark, Canada, Ireland, the USA, and the United Kingdom, just to name a few countries. Like in citizen science, there is no single uniform model of science shops, because they still largely depend on regional boundary conditions. For instance, in Austria and Germany science shops are extra-university research institutions. Some science shops function as intermediaries by directing research requests to interested students, others conduct most of the research by themselves. There are science shops that work the other way around, too, by contacting civil society organisations who might be interested in research a student would like to conduct on their behalf; some are available for answering questions which do not warrant a research project but can be answered with less effort, like a non-profit environmental helpdesk.

### Democratised science?

Science shops seemed to make the barrier between the sciences and the publics permeable. However, what if there is research that never knew such a barrier? Public archaeology in Arkansas might be such a case. Barnes (2007), a scientist working for the Arkansas Archaeological Survey (AAS) says that from its origins, archaeology in Arkansas was a citizen science. In 1932 the AAS was founded out of the concern that construction work and agricultural techniques literally destroyed cultural memory. This concern was shared by legislators, archaeologists and publics alike. AAS involves volunteers in archaeological service since the early 1960s. The roles go beyond being excavators, beyond providing an ancillary service; they are involved in all aspects of the research process. And then other things the contributions of the citizens scientists lead to the establishment of a new research area, African American archaeology.

### Public engagement with sciences

In their self-understanding, science shops shared with the aforementioned uninvited participation in science and technology and with scientists who sounded alarm about the hijacking of science and technology by the military and industry one concern: they try to bring public interest into scientific communities.

In the 1980s governments experimented with new forms of public participation in science policy. Most famous for this was the Danish Board of Technology, at that time a governmental agency that developed several of today's most famous public participation schemes: participatory consensus conferences[2] and scenario workshops[3], just to name two of them (Irwin, 2015). Since then, these participation schemes have been copied, adapted and further developed throughout the world to give citizens a say in science policy and technology assessment, sometimes as if they can be transferred and implemented without any consideration of the context they originated from. The "participatory turn" (Jasanoff, 2003) was a turn away from former initiatives to promote public understanding of science that aimed at putting down public controversies on GMO and other controversial topics by informing the publics. The understanding of policymakers behind it was that such controversies rooted in an uninformed public that misunderstood the scientific and technological issues and reacted only emotionally to them. Once the facts are made clear, controversies would disappear. However, these controversies did not disappear because of information campaigns, which could even fuel them. As a consequence, especially after the BSE[4] crisis in the United Kingdom, governments changed course by promoting "dialogue-based" engagement in science and technology policy. Controversies have been and are responded to by deliberative formats for arbitrarily selected mini-publics who have no say in framing the issues to be discussed (Irwin, 2015; Stilgoe, 2014; Felt et al., 2007). Under this perspective, citizens are invited to evaluate scientific issues, however, questioning the discourses of professional scientists is not on the agenda. What may have incited controversy may not be discussed. What

[2] A participatory consensus conference is a jury-like, consensus-oriented public engagement scheme which brings lay citizens and experts into a dialogue on policy issues in science (Participedia, 2018).

[3] In its original form, a scenario workshop is a participatory method for developing common visions and plans of actions on mostly local issues. The engagement scheme involves residents, experts, business owners and policy-makers (Participedia, 2020).

[4] Bovine spongiform encephalopathy

appears as an opening up is in fact a closing down (Stirling, 2008), the harvesting of public opinions (Irwin, 2015), despite the rhetoric of openness and dialogue (Felt et al., 2007). Retrospectively, this turn looks more like a strategy for the management of public controversies than as a turn to a transparent regime of deliberative democracy in science and technology policy.

That presently governments promote citizen science might be due to failing campaigns to promote public understanding of science and the limitations of public engagement with sciences and the overpromising of those who pushed for it. Citizen science, understood as direct engagement of citizens in scientific research, could then be the answer to the deficit model - a perspective that someone lacks information or skills to understand and accept something - implicit in public understanding of science and public engagement in sciences. But why is the educational value of citizen science stressed so much? Why are citizen scientists framed as being in need of science education? As it seems, the deficit model in public engagement in sciences is still alive.

# 4 Citizen science as a concept

*Michael Strähle & Christine Urban*

## 4.1 Two conceptualisations of citizen science

When literature refers to the original concepts of citizen science, usually it mainly refers to two concepts that have been created independently of each other during the 1990s (e.g. Woolley et al., 2016; Wikipedia, March 11, 2021; Cooper & Lewenstein, 2016; Kimura & Kinchy, 2016; Strasser & Haklay, 2018): the citizen science concept of Rick Bonney (Bonney, 1996; Bonney et al., 2009a & 2009b) and the one by Alan Irwin (Irwin, 1995). Although, as Irwin (2015) mentions, these two concepts are not completely contradicting or excluding each other, sometimes they are described as if they are (e.g. Franzen, 2019; Cooper & Lewenstein, 2009). For instance, Cooper & Lewenstein (2009) describe Irwin's concept as bottom-up citizen science and Bonney's concept as top-down citizen science. Juxtaposing them is justified insofar as these concepts present quite different understandings of what scientific research is good for and the roles of citizens and scientists. These differences might root in quite different professional backgrounds. Rick Bonney is a well-known ornithologist, Alan Irwin is a well-known sociologist of science and STS scholar. But they also root in different goals. Bonney aimed at volunteer contributions to ornithology, which are supervised by professional scientists, while Irwin aimed at sketching a kind of new social contract between sciences and societies.

#### *Rick Bonney: Citizen science as citizen education*

For today's organisers of citizen science projects Bonney's concept is more relevant than Irwin's. Bonney (1996, Bonney et al., 2009a & 2009b) considers citizen science as an approach to involve volunteers in scientific data collection. As we have seen, such an approach is nothing new in the history of scientific research, and Bonney does not claim to be its inventor, nor does he claim to have coined the term. In 1989, the National Audubon Society, an environmental organisation dedicated to the protection of birds and their habitats, used the term in an awareness campaign on acid-rain (Cooper & Lewenstein, 2016; Haklay, 2015; Mitchell, 1989; Bolze & Beyea, 1989; Strasser & Haklay, 2018), in environmental monitoring. What seemingly contributed enormously to making the term more popular, was the twist Bonney and his team gave to this approach in 2009. In their study commissioned by the National Science Foundation on how "Public Participation in Scientific Research" (PPSR) can improve public science literacy (Bonney et al., 2009a), citizen science became an approach that meets two quite different objectives: cost-effective data collection by volunteers on the one hand and building public science literacy on the other. Interestingly, the term "citizen science" is rarely used in this study; instead, Bonney et al. (2009a) refer to PPSR. In Bonney et al. (2009b) the term "citizen science" is used. The contributions remain within traditional scientific frameworks. By learning how scientific research is conducted, citizens gain trust in the sciences, even more they become good citizens by becoming more engaged in local politics and environmental conservation because they contributed to scientific research and developed a positive attitude towards it (Franzen, 2019). Contributing observational data, an often mundane, ancillary task, is framed as basic education in civic virtues. Bonney et al.

(2009a & 2009b) do not mention the concept of scientific citizenship, a concept used by Irwin (2001) under a critical perspective, but similarities are striking.

### *Alan Irwin: Citizen science as a responsive science system*

Alan Irwin's perspective on citizen science is not geared at an educational objective. He questions the distinction Bonney et al. (2009a & 2009b) apparently make between citizens and scientists. For him scientists are always citizens, and scientists should be aware of this. The issue is less that citizens develop a more positive attitude towards science, but that the science system develops a more responsive attitude towards public interests and needs and a broader understanding of societal, environmental and, yes, scientific issues. Irwin's book is a sociological reflection on the status of different kinds of knowledge and experiences and how the sciences can contribute to today's environmental challenges. As a side note, tackling these challenges is also an important objective for Bonney. In 1996 Bonney stated "that bird watchers will save the world" (Bonney, 1996, 7). Exactly these environmental challenges engage people with scientific research by measuring the toxicity of water etc. because contamination affects them. These challenges and issues are not only scientific ones, they are also social. Their very nature makes it necessary to give citizens a say in tackling them, also in scientific research projects and in setting research agendas. In the tradition of the social movements in science in the 1970s, Irwin demands not to leave the development of solutions for environmental threats only to professional scientists. Being aware of the role the sciences play in reinforcing existing social orders that hinder us from tackling humankind's environmental challenges, he calls for a democratisation of the sciences and hopes for a "pressure 'from below'" (Irwin, 1995, 178, cited acc. to Franzen, 2019).

### *Bonney and Irwin: Similarities and differences*

Bonney agrees with Irwin that citizen science contributes to answering our environmental challenges, Irwin does not consider it as an alternative to 'conventional science' (Irwin, 2015), and both of them will not present their understanding of citizen science as mutually exclusive. However, there are differences between these two concepts that are not sufficiently reflected when reference is made to both of them. For Irwin, participation of citizens in science is valuable because it links research priorities to public benefit. In his concept, citizens are allowed to question scientists' priorities. The question is how we can create spaces for interactions between citizens and scientists to break out of scientific and technological determinism (Mowat, 2011), whereas the concepts of Bonney et al. (2009a & 2009b) could also be understood as marketing of the value of traditional scientific endeavours aimed at the publics (Woolley et al., 2016). If they see a place for public participation in defining research questions is an open question: In Bonney et al. (2009a) they do, in Bonney et al. (2009b) seemingly not. Irwin has a strong focus on public engagement in science by consensus conferences and other deliberative formats (and criticizes their consensus orientation and how they are designed); Bonney et al. (2009a) deliberately excluded them when conducting their study.

Because of their differences in respect to the objectives, benefits and understanding of the roles of scientific research, these two conceptualisations of citizen science cannot be easily amalgamated with each other. The question remains how the reference to Irwin's and Bonney's conceptualisations of citizen science together made by citizen science practitioners and theorists on the one hand and political decision-makers on the other came about and what functions it performs. It multiplies the uses of the term "citizen science" to an extent that seemingly every participation in scientific research, in data collection or by informing science policy, providing computing power or gut samples, can be called citizen science with some justification.

## 4.2 Further conceptualisations and definitions for "citizen science"

"Citizen science" is a label attached to many approaches involving publics in research processes: participatory monitoring, community-based research, scientific crowdsourcing, biohacking and participatory action research, just to name a few (e.g. Wikipedia). Quite a long list could be compiled of all the definitions of citizen science that have been made. Just to list a few ones:

The **Oxford English Dictionary** defines citizen science as

> *scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions.*

**Lexico.com** defines it as

> *The collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists.*

The **Green Paper on Citizen Science**, published in 2013, defines citizen science as

> *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.* (p. 6)

And in its **Open Science Survey** (2020), the European University Association defines citizen science the following way:

> *Citizen science is a broad term, covering that part of open science in which citizens can participate in the scientific research process and different possible ways: as observers, as funders, identifying images while analyzing data, or providing data themselves.*

In a **concept paper** on the applicability of citizen science in departmental research of the **Federal Environment Agency in Germany** (Rückert-John et al., 2017), the following working definition can be found:

> *Citizen science comprises voluntary activities that contribute to scientific knowledge and research (Translation by the authors) (Original: Citizen Science umfasst ehrenamtlich durchgeführte Aktivitäten, die zu wissenschaftlichen Erkenntnisgewinn und zur Forschung beitragen).* (p. 19)

As the European Commission writes in its Science with and for Society Work Programme, any definition of citizen science is disputed. As a consequence, the European Commission describes her understanding of citizen science in the Science with and for Society Work Programme 2018 - 2020 as follows:

> *Citizen science is emerging as an important policy orientation but is still largely unexplored. It covers a range of different levels of participation: from raising*

*public knowledge about science, encouraging citizens to participate in the scientific process by observing, gathering and processing data, right up to setting scientific agenda and co-designing and implementing science-related policies.* (p. 40)

And on the following page citizen science is described as

*(…) citizen science should be understood broadly, covering a range of different levels of participation, from raising public knowledge of science, encouraging citizens to participate in the scientific process by observing, gathering and processing data, right up to setting scientific agenda and co-designing and implementing science-related policies. It could also involve publication of results and teaching science.* (p.41)[5]

Instead of clear definitions we can find characteristics of citizen science that coincide on the most general level only: that citizen science involves members of the public in scientific processes. These members of the public can be qualified and professional scientists, too, probably from other scientific domains than the ones they contribute to when participating in a citizen science activity as a volunteer (e.g. Transcribe Bentham). However, there seems to be a common understanding that citizen science engages members of the public who lack formal qualifications for it. This applies to descriptions and definitions of citizen science following the conceptualisation of citizen science by Bonney et al. (2009a & 2009b). To make things more complicated, as we will see in Chapter 6 on categorisations and typologies there are other conceptualisations of citizen science, too, that have a broader, normative understanding of citizen science that includes public participation in science policy without claiming that activities such as consensus conferences and crowdsourcing of data are citizen science (e.g. Irwin, 1995). Definitions of citizen science can be clear and appropriate for specific purposes and specific activities. However, we cannot expect a general definition of citizen science that suits all purposes.

A definition is always a decision, but also not making a definition is a decision, too, with practical implications. Some scholars find that clear definitions would be too deterministic and exclude many projects ((e. g. Auerbach et al., 2019). But how can we characterise citizen science without a definition or at least criteria for exclusion? How can there be a responsible policy on citizen science without a clear description what constitutes it? Clearly characterising or defining citizen science would help to present a clear picture what is citizen science and what it is not. Up to now, the sometime vague uses of the term citizen science - a vagueness that, as we have seen, is held up by some citizen science practitioners - allows to attach citizen science as a label to a very broad range of research projects that involve lay persons as participants, contributors of computing resources (e.g. SETI@Home) or gut samples (Del Salvio et al., 2016; Fiske et al., 2019) and even subjects of research such as interviewees, irrespective if they contribute actively to research or are persons who are investigated. They can downplay contributions of cooperation partners who have acquired in-depth expertise in different ways than by studying at university by calling them "citizen scientists". The too unconditional use of the term citizen science creates a free-riding problem. Grant applicants could use the label to win reviewers sympathy. Project owners could use it to safeguard themselves against criticism from peers by referring to the "democratic" or "educational" potential of their projects, and they

[5] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-swfs_en.pdf

could safeguard themselves against criticism from outside scientific communities by characterising their projects as scientific ones. Using the citizen science label allows scientists to some extent more flexibility to react to criticism by peers, research funders, policy-makers and society at large (Guerrini et al., 2019). In this respect, tackling the vagueness of the term citizen science is an issue of research integrity and social responsibility.

***What is citizen science, and do we need to define it?***

There is no consensus about what citizen science exactly means even among researchers who are highly specialised on the topic. Just as research funders and policy makers use it differently: sometimes quite differently:

> *[…] no central authority or governing body oversees the field, and even agreeing about who counts as a citizen scientist is challenging.* (Rasmussen & Cooper, 2019, p. 1)

But there has not only been a broad consensus that the term is fuzzy. There is not even consensus if it should be defined clearly.

The term "citizen science" has made a remarkable career in terms of scientific publications and funding schemes. Citizen science policies are developed. Some questions emerge which would go far beyond this report: What do those who are active in citizen science contexts expect to gain from it? Who expects what challenges citizen science to solve?

But in spite of its extensive use and the many promised benefits for society, even highly specialised scholars are far from agreeing what it exactly means. The only broad consensus they have reached is that the term is indistinct. There is also no consensus if this is a disadvantage. If a terminology is desirable or not remains contested. Which is remarkable in view of the many benefits for science and society that are postulated for a high variety of conceptualisations that partially are incompatible. Those who argue against rigid definitions, see a risk of excluding activities and narrowing down the diversity of "citizen science" (Heigl et al., 2019a; Auerbach et al., 2019; Heigl et al., 2019b).

But how can one talk about citizen science, let alone investigate the phenomenon in its different facets and assess the many promised benefits for science and society without having a clear common understanding of what it means?

Among those who are firmly advocating for taking steps towards developing a binding international definition are Heigl et al. (2018) which they see as necessary to develop standards for citizen science. They bring the still unsatisfying situation to the point:

> *But what exactly qualifies as citizen science? It is interpreted in various ways (1) and takes different forms with different degrees of participation (2). In fact, the label citizen science is currently assigned to research activities either by project principal investigators (PIs) themselves or by research funding agencies.* (Heigl et al., 2018, p. 8089)

One could add that it is also other scholars who sometimes assign the term rather arbitrarily, too, because of the mentioned lack of clear definitions.

In spite of intensified discussions as the term "citizen science" is used more and more often, the challenge to find clear definitions prevail, as even the most recent literature shows. Vohland et al. (2021) still ask the question "What is citizen science?" and describe it as broadly referring to "*active engagement of the general public in scientific research tasks.*" (Vohland et al, 2021, p. 1). But, even this very general and inclusive definition excludes some activities which are presently recognised as citizen science: citizens' deliberation on research policies would not belong to "research tasks". Also, when individual citizens or NGOs request information or more research on a certain question, they may trigger research without further engagement. The umbrella label citizen science frequently also includes innovation and development (sometimes) happening in fab labs or maker spaces, but these are usually not called research tasks, either.

Hence, adapting the above sentence, in the broadest sense one could say that presently citizen science is a rather undefined term that refers to the active (or passive) engagement of the general public in activities that are in some respect related to science and/or innovation, excluding those members of the public who are (substantially) paid for it.

### *Déjà vu? Similar debates on public engagement and citizen science terminology*

Some debates on citizen science conspicuously remind of debates on public engagement we have had since the 1990s at least. Definitions and descriptions of citizen science include references to fields as different as education, science and public participation, a complex of references that resembles the meanings of public engagement (Lewenstein, 2016). Some other similarities between citizen science and public engagement are striking. As no definition of public engagement seems to capture all shades of meaning, no definition of citizen science is accepted as conclusive; and as it is always open to discussion when participation begins, so it is always open to discussion what is part of citizen science and what is not. Eitzel et al. (2017) argue for using the term broadly so it is more inclusive. Other people than professional researchers participating in citizen science activities maybe do not see an advantage of such an ambivalent concept or term. Such ambivalence might be praised as democratic flexibility because it allows for inventing more and more schemes to involve citizens in scientific processes and call it citizen science. But that was the case with public engagement too. Another commonality between public engagement and citizen science is the imagination of two different spheres, science and society, a quite artificial distinction, if we take into account that, as Sheila Jasanoff (2014) put it, we children of modernity are enmeshed in science and technology. And, just to name a few, as Bruno Latour, Ulrich Beck and Hans Jonas made clear, our societies have become laboratories for scientific experiments. What is the use of making a distinction between science and society? What Bauer & Jensen (2011) said about public engagement may apply to citizen science, too: "This ambivalence in the definition of public engagement activities allows scientists to police the boundaries of science/society flexibly and with their own interests in mind." (Bauer & Jensen, 2011, p. 4). Meanwhile, definitions of public engagement and citizen science have multiplied, so have terms that refer to science/society relations, especially in European research programmes.

### *Debates on terminologies in citizen science*

The terminologies in citizen science are subject of ongoing debates among scholars, policy makers and practitioners. It would go beyond the scope of this report to describe all the suggestions made by different authors. It suffices to say that no practicable solution has been found yet. To give a picture of the current situation the authors give some examples of different attempts to shed light on what terms are used.

One strategy is to apply quantitative methods to investigate which vocabulary is used in the field of citizen science. Statistical analyses of literature, websites or online media can also shed light on the frequency to which the investigated terms appear. This approach can give a rough idea of their popularity in different research fields, the contexts in which they are used and how it changes over time. Just to give an idea of the abundance of expressions that have been invented over the time, the authors start with one work that restricts itself to the area of geography alone. It is only an example among others of how scholars tackle the issue of terminology.

Linda See et al. (2016) performed some extensive research on which terminologies have been applied in literature and on the web connected to passive or active involvement of lay people in science and/or crowdsourcing in the geospatial field. Their overview gives a good picture of the lack of clarity in terminology in citizen science, crowdsourcing and other forms of contributing geographic information and how the use of expressions can change over time. (See et al., 2016, p. 8).

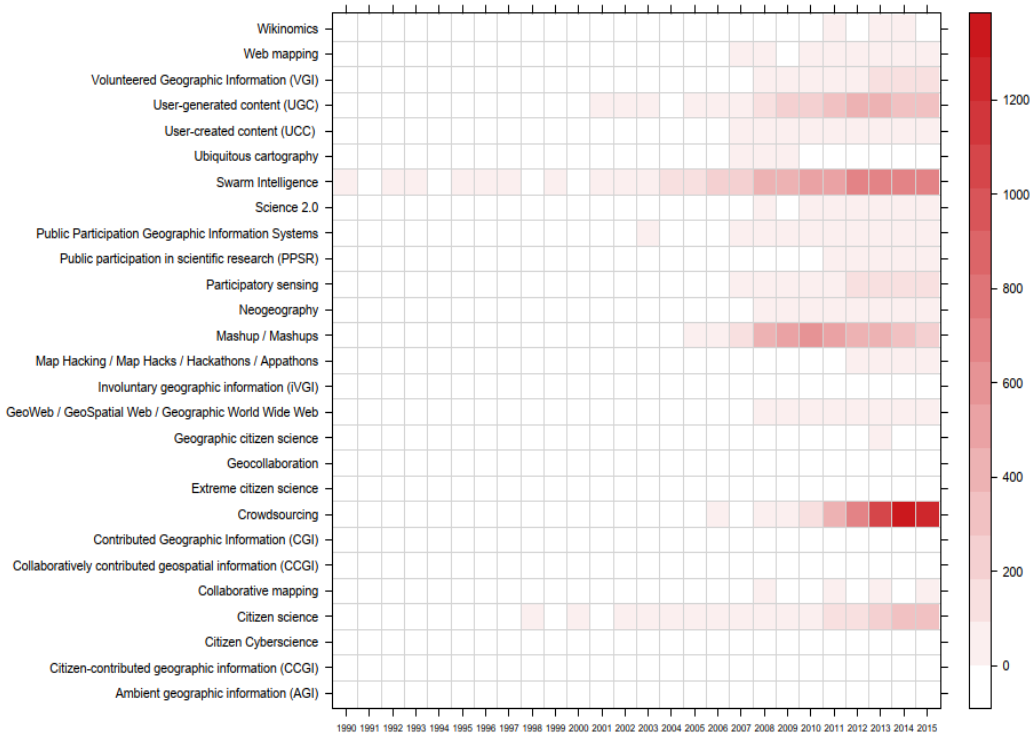


**Figure 2.** The frequency of occurrence of different terms found in the literature relating to Crowdsourced Geographic Information.

(See et al., 2016, p. 9.)

See et al. (2016) conducted then a Google Trends analysis of these terms. Interesting in the CS Track context are their results for comparing "crowdsourcing" and "citizen science", the latter appearing more often from 2007 on and then staying comparingly constant until 2015, while a stronger raise of the term "crowdsourcing" is observed (See et al., 2016, p. 9)

In their conclusion See et al. write

*The majority of sites do not collect very much information about participants. This may make participation easier but it means that very little research can be undertaken on the relationships between participation, data quality and demographics, or on the understanding of motivational factors.* (See et al., 2016, p. 17)

They confirm that there is much more than a merely terminological problem when talking about engaging other people than professional scientists in research projects: The difficulty, or sometimes impossibility, to assess which people are actually involved, further complicates the understanding of the term "citizen science".

Kullenberg & Kasperowski (2016) performed another quantitative analysis. Their scientometric study is not dedicated to a certain area but to citizen science in general. In their introduction they ask - like other scholars - "What is citizen science?" and answer it similarly as most of them:

*The meaning of "citizen science" is in fact not very clear, particularly when formulated on a science policy level, where it is often defined too broadly without making the distinctions that scientists work with.* (Kullenberg & Kasperowski, 2016, p. 2).

They approach the issue with an analysis of publications referenced in Web of Science (WoS) and of the co-occurrence of related terms. Interestingly, they find no scientific output for the majority of projects they retrieved, which is why they conclude that primarily many citizen science projects do not have a scientific objective (Kullenberg & Kasperowski, 2016). This would be worth to be further investigated. Does the lack of scientific output prove that there was no scientific objective in the first place? There may be other reasons for not leaving such traces in the WoS: A number of citizen science projects with scientific goals may not have succeeded in publishing their results, and other citizen science projects may not have thrived for publishing in high profile journals at all. (The paper refers to non-professional contributors as "volunteers",)

Either way, if "citizen science" had no substantial scientific goal, it would not be clear why it should be called "science". Other terms like "science education" or "science communication" might then be more appropriate. Having no substantial scientific goal would also contradict the 10 principles of citizen science launched by ECSA, which are widely accepted now (Robinson, 2018, p. 29 et seq.).

A radically different approach of shedding light on the term "citizen science" than researching how it has been used in the past, is directly asking those who are presently making use of the term to decide on how to use it in a less fuzzy way. Such negotiations of definitions can take the form of surveys or consultations.

Much attention has received a recent initiative, a cooperation between EU.CitizenScience, a project funded in Horizon 2020, and ECSA – The European Citizen Science Association, to characterise citizen science. At the time of writing, details on the methodology are not published yet, only the results and explanation notes are found at Zenodo. Citizen science scholars and citizen science practitioners developed vignettes[6] which described fictional examples of diverse citizen science activities. People were invited then to comment on these vignettes and to decide which of them should be included in the term citizen science or excluded. A version 1 of the

[6] According to the Oxford English Dictionary, a vignette is "a brief evocative description, account, or episode" (https://www.lexico.com/definition/vignette).

document dates from April 2020, apparently an ongoing process is intended (Hakley et al., 2020a & Haklay et al. 2020b).

Because there is no detailed description of the methodology yet, it is not quite clear how far the "characteristics of citizen science" should be regarded as a research study or a consultation. If it is the first, there are few methodical questions. Why using vignettes? They can hardly be formulated in a neutral way. If the texts are loaded, they can steer the reader into a certain direction and thus influence answers. Vignettes have been used in psychology for quite specific research questions. In the second case, if it is intended as consultation, then it is part of direct or indirect political decision making in the research area. Deciding on what can be called "citizen science" most likely co-determines what will be eligible for funding under the label "citizen science". In that case, a higher degree of transparency would be called for. It should be clear who was involved in such a decision-making process, how the invited were selected, how results were documented. Obviously, the characteristics do contain elements of consultations, but it was not fully illustrated yet to what degree the procedures tried democratic approaches.

Characterising citizen science and the meaning of the term is an ongoing endeavour of citizen science advocates, proving (again) the non-existence of satisfactory definitions. This is notable insofar, as under this fuzzy label there exist already research policies, green and white papers, and funding schemes. Albeit still undefined or in spite of its blurriness, citizen science is also included in the MoRRI indicators, a monitoring system based on quantitative indicators for measuring Responsible Research and Innovation activities, and counts as a sign of "responsible research and innovation" (e.g. Stilgoe, 2019).

**Conceptualisation of "citizen" and of "scientist"**

The core concept of citizen science consists in a distinction between professional scientists on the one hand and citizens who are not professional scientists on the other hand. Without this distinction any scientific activity would just be science.

According to Encyclopedia Britannica, science is

> *any system of knowledge that is concerned with the physical world and its phenomena and that entails unbiased observations and systematic experimentation. In general, a science involves a pursuit of knowledge covering general truths or the operations of fundamental laws.* (The Editors of Encyclopedia Britannica, n.d.)

Other encyclopedias present similar definitions.

None of these definitions say that science is defined by any characteristics or educational background of those who carry it out, which weakens the concept of citizen science.

Hence, one could say that citizen science is about participation of persons in research and/or innovation who would normally not take part in it (or not be noticed as taking part in it), without (substantial) pay. The vagueness of the concept of the citizen who is different from the ordinary scientist is also expressed by a heated discussion among citizen science practitioners and scholars about how to call him or her.

Needless to say: No satisfying solution has been found yet. How could it be possible to find a common name for the participants of very different concepts of citizen science? They may be students, pupils, volunteers, practical consultants, amateur inventors, participants in consultations or local interest groups? It seems that the discussion about which characteristics citizen scientists must have to turn science into citizen science is replaced by a discussion about perceived or assumed sensitivities of these “citizen scientists”.

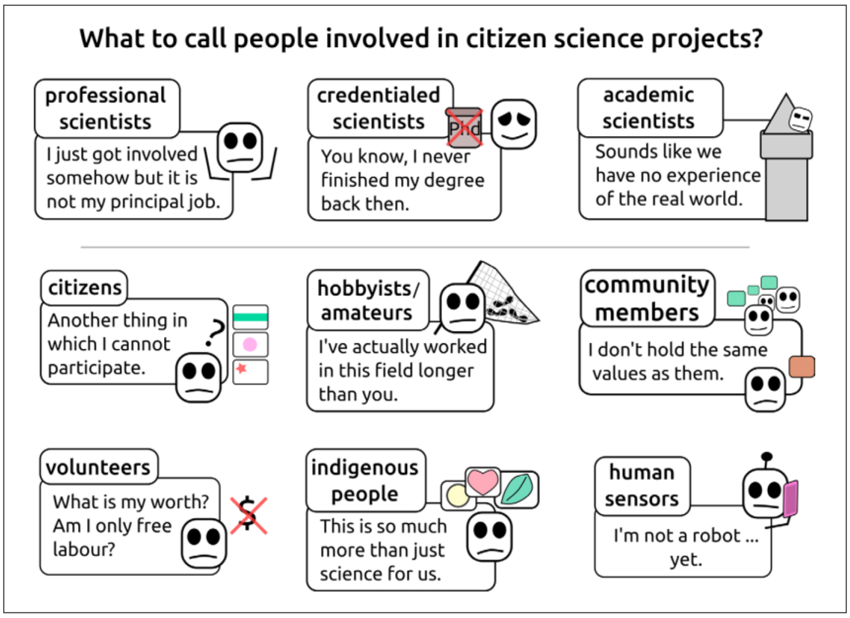


**Figure 1:** Illustrated examples of negative interpretations of commonly used names to describe people participating in citizen science, selected from our list of terms. Every term is used and interpreted in many different ways in different situations; this graphic highlights interpretations commonly encountered by the authors (also see Tables 3 and 4, particularly 'caveat' column).

(Eitzel et al., 2017, p. 5)

It appears that problems of terminology in citizen science are mainly discussed by scientists. But do we know how far people outside the academic field of citizen science are interested in this terminology, given that there is not enough evidence on how far citizens are even aware that they are contributing to science or know that there is such a discussion on how they should or should not be named within the academic citizen science communities?

Probably the best-known scholarly contribution to this topic was written by Eitzel et al. in 2017. Notably, the authors come from science and/or educational backgrounds and had started a discussion on the CSA mailing list about how to name citizens. In the following a working group developed which conducted an analysis of the different understandings of citizen science and related terms (Eitzel et al., 2017). In spite of careful consideration of a large number of possible terms, the original question, how to call people participating in different roles in citizen science, could not be solved: For any possible term they analyse, the authors find also a caveat, a way to interpret the term as problematic in one way or another and depending on the context. While some terms obviously contain negative connotations or show condescension, there are also terms for which the alleged caveats look a bit artificial. A “professional researcher” is put into the same group as a paid or employed researcher (Eitzel et al, 2017, p. 12). But a volunteering professional remains a professional – in contrast to being paid or employed. For a “volunteer scientist” they see a potential negative implication of being “inexperienced or not worth to be hired”

(Eitzel et al., 2017, p. 12). But "volunteering" just indicates not being paid for a task, which refers to neutral fact and not necessarily a value judgement. That a "contributor" would be similar to a "donor", who is mostly considered somebody who bestows funds or goods (Eitzel et al., 2017, p. 14), might not be a too frequent interpretation of the term.

The issue of finding terms for people participating in citizen science could be complicated by some scientists' tendencies to overestimate their status in society. In citizen science communities, whose members are mostly scientists and scholars, a power imbalance between professional scientists and people who have no academic education is perceived, with the latter in the weaker position. But how realistic is this picture nowadays? Since a few decades the number of people, who acquire higher education, has risen. In 2019, more than 40 % of the 30 - 34 years olds in the EU had completed tertiary education (EUROSTAT, visited 2/2021). If average professional scientists see themselves as socially superior nowadays, this might be rather wishful thinking and/or denial of the typical working conditions academia offers to younger scientists. In spite of the egalitarian rhetoric, some citizen science scholars seem to consider it embarrassing for a person not having studied at a university. This may be one reason why they see any explicit terms as "problematic" and one tries to circumscribe. But at the same time, it remains speculation how much citizen scientists/lay people/volunteers really care about how professional researchers call them, because they are seldom asked.

### *The prefix "lay" (e. g. lay researchers/lay persons)*

Although it seems to be widely acknowledged that the use of "lay" in connection with participants in citizen science would be highly problematic (Eitzel et al., 2017, p. 14 et seq.; Strasser et al., 2018, p. 55), the reasons for this condemnation of this prefix are not fully clear, especially in view of the fact that "lay preacher" or "lay judge" are not at all derogatory terms.

The underlying confusion might lie again in the different conceptualisations of citizen science: Being a lay person is not synonymous with possessing no university degree. But in the context of citizen science, it is interpreted that way sometimes. A prominent example for doing so is Peter Finke, a philosopher of science, who published on citizen science. The title of one of his books can be translated as "the underestimated knowledge of laypersons" and gives the example of Irmgard Sonneborn, a saleswoman, who accumulated so much knowledge in her leisure time that she became a renowned expert of botany - even though she never went to university. (Finke, 2014, p. 13). This use of the term denies that expertise could be acquired by autodidactic learning. People who have accumulated extensive knowledge over many years of self-study and who are even recognised by scientists are usually not defined as "lay persons". Neither the Oxford dictionary nor the Duden dictionary, the authoritative dictionary on German at least in Germany, are specific on how much expertise needs to be acquired to go beyond the status of a "lay person" (in a certain field). It is the question how often the term "citizen science" means to include research cooperations between university-educated, specialised scientists with other high-level (although unpaid) experts. These can be people who have subjected themselves to laborious self-study and/or who have worked for many years in the field of interest. In some cases, indigenous people could be meant who possess extensive traditional knowledge that has been accumulated over generations of observation and experimentation (e.g. Walajari, 2019; Liebenberg et. al., 2017). At least, differentiation between working with other experts and people without specific knowledge is necessary, as these are entirely different conceptualisations of citizen science. The benefits which citizen science proponents most passionately claim would rather support the latter concept: Usually citizen science proponents emphasise the advantage of involving persons who have no specific expertise in a field (see: chapter benefits) and would otherwise not engage in knowledge building.

### *Does citizen science necessarily involve a cooperation with volunteers?*

Many authors assume that citizen scientists are volunteers[7] who engage in science projects. The term does not do justice to the full range of meanings attributed to citizen science.

"Volunteers" is not an expression that informs much about who has to cooperate to make some scientific endeavour citizen science. Firstly, in some cases scientists organising a project are not paid, and thus volunteers like the citizen scientists.[8] Secondly, if citizen science activities are carried out in formal education, "volunteers" would hardly apply to students or pupils. In cases where citizen science is part of a curriculum, their participation is obligatory. Even if citizen science is organised as a voluntary activity that is not a direct part of school lessons or university courses its fully voluntary character remains questionable. Hence, not all conceptualisations in citizen science see the involvement of volunteers as necessary.

Thirdly, and maybe most importantly: If one gives one's opinion in a public consultation one usually would not use the term "volunteer" either. Volunteering refers to working for a good cause rather than saying what one thinks about an issue. Defining the act of "making decisions" – not the process of coming to this decision – as "work" could have some consequences for democracy, which would merit a research project of its own.

### *Are scientists cooperating with "ordinary" citizens in citizen science?*

The term "ordinary" seems to be often accepted for other participants in citizen science than professional scientists. For instance, the authors found it used by a COST action on citizen science[9] and many others. The term "ordinary" suggests that researchers are "special" while most other people are not. (By the way, this contradicts the manifold initiatives to make young people consider science careers by promoting that science is an ordinary profession occupied by ordinary people like many others). Whereas the term "lay person" always depends on the specific context, and even the most successful scientists are lay persons in most areas, "ordinary" is a statement on the person as a whole.

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[7] According to some authors, even the frequently used term "volunteer" could be problematic as it focuses too much on participants not being paid or even questioning the value of their work (Eitzel et al., 2017).

[8] Of course, this does not exclude any future payoffs in the form of higher earnings because of publications and stronger reputation.

[9] CA15212 - Citizen Science to promote creativity, scientific literacy, and innovation throughout Europe, https://cs-eu.net/about, last access on 8 February 2021.

### *Citizen scientists*

The term is confusing on several levels. A professional scientist is as much a citizen as a lay person. The term "citizen" can be understood in different ways and can refer to legal citizenship, however, it is clearly not the intention of citizen science proponents to exclude anybody. Additionally, many tasks carried out by citizen scientists are not tasks predominantly carried out by scientists. Instead, collecting data, taking probes, and many other tasks have traditionally been carried out by *auxiliary* personnel employed by scientific institutions. Hence it boils down to a definition of a citizen scientist as somebody who is not paid for performing scientific tasks or ones supporting scientific research. When we do not know who actually participates in a citizen science activity, the term "citizen" is a wildcard. Because of such an indeterminacy the term "citizen" can become a projection screen for more or less unfounded ideas, who these citizens actually are, who contribute to a scientific project, and of insufficiently justified, sometimes even patronising, claims by project organisers what benefits citizen science has for "citizens".

The terminological contradictions between the different scholars do not end here. There is some indication that citizen scientists do not identify with it. Tancoigne (2019) analysed the use of the term "citizen science" on Twitter and finds that

> *Many participants in citizen science projects with Twitter accounts do not use the labels "citizen science" or "citizen scientist" in their profiles. These are terms constantly used by organizers and the media, but even the top participants do not include the expression in their bios.* (Tancoigne, 2019, p. 11)

It is unclear if they do not know the term or if they reject the expression. Some empirical research may be indicated, because we did not find much about how far citizens are aware that what they do is called citizen science or if citizens do not like to be called citizen scientists. We found anecdotal evidence that some biohackers prefer to be called scientists because they consider what they do as rigorous research. For them the term "citizen science" seems to have connotations of amateurism and non-professional science (Guerrini et al., 2019). In other contexts, the term "citizen science" can have undesirable connotations, because of the political connotations. In Japan, e.g., there are concerns using the term "citizen science" because of its connotations of oppositional political activism, especially anti-nuclear activism. Situating oneself against the government makes it more difficult for everyone to join such an initiative (Kenens et al., 2020). According to Kenens et al. (2020) only one of the citizen science organisations they investigated, used the term "citizen science", interestingly it is the one that is mostly cited in the citizen science community - Safecast. With the exception of Safecast, these investigated initiatives - all of them are bottom-up initiatives that were created after the Fukushima accident - do not aim at contributing to science, instead they want to serve their community. Scientific research has a purely functional role here: measuring radiation accurately. In some cases, experts have been consulted informally only, in others they were co-founders of such a citizen group; nevertheless, the main objective was never the scientific one. Is this citizen science or something different?

Debates about terminology of citizen science have primarily paid attention to problematising what is meant by "citizen", but neither what is meant by "science" nor what these non-professional researchers and contributors called citizen scientists experience as science, as if it were quite obvious what science is, as if science and technology would be neutral, not being co-created by the power struggles in the social and economic systems they are part of. What science is meant here? Mostly natural scientific research or also humanities research? Moreover, such debates about terminology are mostly led by scientists. As Lewenstein (2016) points out, the implications of labelling citizen science as "science" are far from being clear. For some practitioners, citizen science is a new approach to science, for others it is a kind of counter-science, some consider it a kind of teaching method. The list could be enlarged.

In a Commission brochure on citizen science, the authors write that "it is important to distinguish between the concepts of public engagement, co-creation, citizen science, open science and science communication to clarify the purposes of each in the context of Horizon Europe" (European Commission, 2020, p. 27). We agree that this terminology is confusing. But why define all these terms? Do we need them all? Maybe it is a proper solution to apply the law of parsimony here: Words should not be multiplied without necessity. The potential confusion about the term "citizen science" is created by the temptation to apply it as a general term for a lot of practices in public participation in scientific processes and science education. These discussions about terminology and meaning can partly be avoided by having a look at the universe of participatory practices and reminding oneself how these practices are called instead of trying to apply a general term as a catch-all word for all these practices.

Some scholars – e. g. Eitzel et al. (2017), recommend that participants should be given the choice how to be named (Eitzel et al., 2017). In many situations this may be a practical solution – but for researchers analysing citizen science, potential funders or regulating bodies governing legal and ethical issues, developing more clearly defined terminologies would ease talking about issues related to citizen science.

# 5 A literature review on citizen science-related topics

## 5.1 A description of available peer-reviewed scientific literature

*Michael Strähle & Christine Urban*

What do we find when searching literature about citizen science? In a nutshell, we find an abundance of case studies, essays, reflections and reports. Most of the literature consists of presentations of projects by researchers who conducted them, however, reviews and comparative analyses of issues of citizen science are rather scarce so there is only little empirical evidence on them. The available empirical evidence is not sufficiently comprehensive to allow for well-founded assessments of the state-of-the-art in citizen science.

We used mainly three sources to get a picture of what has been published on citizen science:

Google Scholar: A research was performed in May 2020 which gave back thousands of hits. Searching with the same terms year by year gave back considerably different numbers than a search over several years. Google Scholar is not very selective, many of the hits were not cited in other literature. To cut down hits, mostly retrieval of titles in combination with keywords of special interest was performed.

Scopus: Information retrieval also in this scientific database from December 2019 - February 2020 and October 2020 - January 2021 yielded a similar number of hits and trends.

Pubmed: May 2020: Gave back literature mainly but not only in the health sector.

Google Scholar and Scopus gave an impression of the incredible amounts of text that has been produced and presented on the topic of citizen science.

While Scopus and Pubmed are scientific databases that contain mostly peer-reviewed scientific literature, Google Scholar presents a broader range of scientific publications that include preprints and grey literature such as research reports.

In most of the case studies their authors tend to depict a project as an example of what citizens scientists can do. As stated before, often their authors are the project organisers themselves. Many of them paint a quite positive picture of the achievements and impacts, but it is not clear how many contain also critical self-reflection. Secondary analysis of and secondary research on a random selection of these reports and case studies - most of which have not been subjected to deeper investigation - could yield valuable insights to citizen science: the narrative of project organisers, their perspective, their worries, how they like to see the project and too be seen. And sometimes there is a (self-)critical review that does not embellish errors, cul-de-sacs and unsolved problems. The latter might not be fashionably optimistic, but pointing out issues that need improvement are the main chance that they can be improved. Unfortunately, such a secondary analysis across a considerable number of projects would go beyond the scope of CS Track. It would require not one but many projects to answer all open questions that came up during literature research.

The literature we use in D1.1 is mostly restricted to peer-reviewed literature and/or work that has found recognition within the citizen science community.

## 5.2 Citizen science and its relations with the science system

*Michael Strähle & Christine Urban*

*Benefits: Claims and identifications*

Not only is there a broad range of interpretations of what activities can be tagged as citizen science, there is an equally broad range of hopes how citizen science can be beneficial in various dimensions. Several scholars have analysed the literature, identified and categorised the various promises made about citizen science adding to the common good.

For instance, Kimura & Kinchy (2016) carried out an extensive literature review and identified seven claims among many other claims that received the most attention. They found that - according to citizen science scholars

> *Citizen science can enable researchers to overcome a variety of constraints on their research. It can have an educational function, expanding scientific literacy and environmental awareness. Some claim that citizen science empowers participants in a variety of ways, such as building social capital and leadership skills. Citizen science projects can level inequality between experts and laypeople and foster collaboration. Citizen science can also help social movements by filling gaps in knowledge and challenging official accounts. There are indications that citizen science can bring about policy change. It can also be used to catch polluters and bring them to justice.* (Kimura & Kinchy, 2016, p. 333)

The authors conclude that no single project can show these virtues at the same time, "particularly since some of them are contradictory" (Kimura & Kinchy, 2016, p. 333).

The impression that literature is somewhat overly optimistic about what citizen science can do and achieve for individuals, science and society is also confirmed by Strasser et al. (2019). They allocate the diverse promises to three groups, which, as they think, should be critically evaluated:

> *Among the various kinds of participatory research projects, those promoted under the banner of "citizen science" have produced a particularly dense promissory discourse. Three kinds of promises are made: a greater democratisation of science, better scientific literacy, and new scientific breakthroughs.* (Strasser et al, 2019, p. 62)

Our own literature research confirms what is stated by these scholars: a broad range of benefits are claimed. (Of course, they also depend on the understanding of citizen science and its goals). Identified and claimed benefits are mostly indicated without further explanation or based on anecdotic evidence that might be true for the specific projects in which they have been identified. There are undoubtedly benefits that are very plausible, and for some projects positive evaluations are available.

However, benefits cannot be assumed for citizen science in general: They have to be assessed project by project.

At the time of writing, no systematic assessment of the benefits of citizen science for scientific research could be found, even not for specific areas such as biodiversity research. Some benefits can be deducted, e.g. on the basis of methodological considerations, however, for some benefits there is only anecdotal evidence which cannot be generalised.

Benefits for the advancement of the state of research in some areas brought about by citizen science are indicated. Scientists may have a career benefit from contributions by citizen scientists, however, seemingly such benefits have not been investigated so far. Investigations of researchers' career profits - and also losses - would help us to deepen our understanding of impacts citizen science may have on advancing scientific knowledge, incentives and disincentives, and barriers and enablers for scientists to engage in it. At the time of writing, the issue when citizen scientists expect a personal benefit from contributing to scientific research and what benefit they expect has not been investigated across a sufficiently broad and diverse range of scientific projects already. Probably it can be fairly assumed that citizen scientists do not expect a personal benefit if the contributions require little effort. This is in line with research on success factors for citizen science projects. These studies identified as a success factor very small tasks for citizen scientists that do not require much scientific training or cognitive efforts (e.g. Riesch & Potter, 2014). Tasks such as taking a photo with a smartphone and loading it up to a platform are very minor contributions that can take little time unless contributors feel compelled to engage in a competition, who takes the most professional picture. However, citizen scientists might be interested in benefit sharing if the research they contribute to can be commercialised unless they do not decline participating in such projects (Resnik et al., 2015; Guerrini et al., 2018).

The general question here is: Who identifies what benefits for whom? In this chapter we focus on benefits identified by scientists; benefits identified by policy-makers will be discussed in D1.2. Since we rely on scientific literature, we discuss what specific benefits of citizen science scientists identified. In their understanding of citizen science most of the authors seem to follow the Bonney model that situates citizen science in a classic epistemic framework of scientific research with participants in traditional roles. When the main objective is to gain scientific insights and to publish them, this is no surprise. Citizen initiatives that design their own research activities often do so to pursue a purpose that goes beyond a scientific one, and research might be only one of several other means to reach the initiatives' objectives such as environmental or health protection. Of course, there is no clear-cut separation between scientists on the one side and activists on the other. Activists may use scientific evidence to promote their uses, and scientists may have similar ambitions as activists, however, their reward systems are different. The main objective of activists is not to be rewarded by publishing often cited peer-reviewed articles in scientific journals with a high impact factor, by patent applications or by receiving scientific prizes or grants.

Benefits identified by scientists can be clustered into ones for the advancement of scientific research, the environment and ecological systems, citizens, and society at large.

In principle some benefits to scientific research brought about by citizen science can be

- discoveries and insights that could or would not have been gained without contributions by citizen scientists because of their skills, computing power they provide, or data not to be had otherwise than by citizen science;
- recognising of knowledge gaps (Elliott et al. ,2019) and blind spots;
- generating new research questions (Elliott et al., 2019), new research topics or new perspectives on research topics;
- and cost benefits.[10]

For all these potential benefits we can give examples but they cannot be generalised, especially not across approaches and methodologies. Without extensive research on different citizen science approaches and single activities it is impossible to say how far any potential benefits are typical or not.

Resnik et al. (2015) briefly give examples of benefits of citizen science other researchers have indicated. They identify three main benefits: Citizen scientists are a valuable resource for scientists because citizen science may allow to conduct research projects that could not be conducted by researchers themselves because of their geographical scale, the time, labour effort and, probably, funding they would require. Among other things, citizen scientists provide "free labour" and ancillary science services by gathering data on animal behaviour, environmental pollutants, invasive species and animal and plant populations. However, if this "free labour" goes far beyond small tasks it raises the issue why these tasks are being done by citizen scientists without remuneration. Furthermore, among other things, citizen scientists can contribute to research design, subject recruitment, and dissemination activities and help to take societal needs into account. The second benefit they determine is an educational one: an enhanced understanding of science that translates into public support for scientific research, an empowerment of citizens, and a better understanding and appreciation of nature and the environment. The third benefit they see is a democratisation of science by giving lay persons a say in scientific issues. Although these examples make an impressive list of benefits, it cannot be said with sufficient certainty that they are the result of a systematic assessment. Especially the claim of a democratisation of science by citizen science may not be sustained when critically scrutinised.

### *Discoveries and insights*

Named as specifically successful are the insights and discoveries brought about by players of the scientific online puzzle game Foldit.[11] These players try to "fold" proteins into the most stable state they can adopt. The accomplishments of these ten-thousands players include have been published in Nature several times, in PNAS and PLoS Biology, just to name the most important journals, In 2017 the Entomologischer Verein Krefeld (Entomological Association Krefeld), an association of hobby entomologists that is headed by a biologist who wrote his doctoral dissertation on an entomological topic, proved by a standardised method that in the Krefeld region the "biomass" of insects had declined by 75% in the period 1989 - 2013. The results were discussed in the German Parliament. Apparently academic research had not

[10] See on this also the chapter on economic aspects of citizen science.

[11] *Solve Puzzles for Science | Foldit*. (n.d.). Foldit. Retrieved April 11, 2021, from https://fold.it/portal/

performed such research so far (Hilbrich, 2018). The world's largest data repository on biodiversity, the Global Biodiversity Information Facility, gets half of its data from citizen scientists. According to Irwin (2018), these data have been used in more than 2,500 peer-reviewed papers between 2009 and 2018.

### *Recognising knowledge gaps and blind spots*

Referring to S. Harding and H. Longino, two eminent philosophers of science, Elliott et al. (2019) point out one of the major topics of philosophy of science: objectivity. Generally understood as an attempt that all truth claims rest on impersonal criteria. This is an ideal because scientists may unite around common approaches, general assumptions and even habits, similar to what Kuhn called paradigms (Kuhn, 1962) and Fleck called thinking styles, not around impersonal criteria only. To give scientific minds a body, Haraway (1988) reminds us that our knowledges are situated, essentially partial. For Harding and Longino science is social knowledge that requires diversity to get a more complete picture. This is where also lay participants - that do not necessarily have to be citizen scientists - can play a decisive role: By bringing in other and diverse perspectives, interests, and complementary knowledges and experiences, they can play a valuable role in determining which avenues to investigate and what areas of research deserve more consideration than others and to detect blind spots. (However, scientific research has to safeguard itself from inappropriate advocacy. This applies to industry-related research, too.) Although their contributions may not lead to disruptive innovations or radical technological breakthroughs, it may make research more attentive to societal needs and different knowledges.

### *New research questions*

Involving other people than scientists with whom one shares a thinking style or perspectives can be challenging and also rewarding by generating new research questions. As Elliott et al. (2019) point out, new research questions can also be generated and new inquiries can be facilitated, especially in ecology, by the new opportunities for data collection citizen science allows for.

### *Some forms of citizen science can bring data collection on a new level*

One benefit seen by a lot of scholars is crowdsourcing of data, including the potential of citizen science to collect a previously unimaginable enormous amount of data. This is closely connected with technical advancements that allow the majority of the population to purchase sophisticated smartphones, tablets and similar gadgets, with which it is possible to make high resolution photographs and to include information on the place and the time where/when they were taken.

However, the reliability and quality of data and their collection is regarded as an Achilles heel of citizen science (see e. g. Catlin-Groves et al., 2012; Freitag et al., 2016). There are sites that are more frequently observed by citizens than others, and at different times. More data are gathered in well-populated places (Catlin-Groves et al., 2012) or those that are less remote (Callaghan et al., 2020). Sites in less populated areas, near traffic ridden noisy streets or post-industrial areas tend to remain neglected. As can be expected, some of these data are collected on weekends or holidays because participation in citizen science is also a leisure-time activity (e.g.

Courter et al., 2012). If the subjects/objects of research are moving, as is the case with animals, it matters at what day- or night-time they are observed. Apart from preferences and habits that lead to local and temporal bias, there is the possibility of human error. Some forms of data collection require skills that need training and/or experience (e.g. Kosmala et al., 2016) not to mention the probably rare but not impossible cases of misconduct (Rasmussen, 2019),

But this potential weakness in data collection seems to be nothing that could not be overcome. There is quite a body of literature discussing how to improve the value of the abundance of information that can be provided by a huge number of volunteers (Catlin-Groves, 2012; Callaghan, 2019).

In their review Catlin-Groves et al. (2012) mention measurements like asking clear questions, providing a list of easily identifiable species, relatively rigid protocols, checking conspicuous data and employing well-trusted experienced volunteers, etc. If projects run longer, participants can collect experiences and improve i. a. their ability to identify species. Some projects give the input of contributors with proven reliability more weight.

Other solutions can be based on statistical methods. Callaghan et al. (2019) give examples of how researchers can deal with patchy data collection from "biodiversity sampling events" (BSEs). Investigating the probability of data collection errors and their nature helps to develop targeted remedies (Clare et al., 2019).

For Callaghan et al. (2019) incentives for participants are key, too, such as taking quality of observations into account and not just their number.

Few studies come to the conclusion that citizen science may not save any time or money (see, e. g., Fauver, 2016), as data collected by lay persons needed so much afterwork, that would have been more efficient to have it done by trained employees. General statements should be avoided, an evaluation on a case-by-case basis is necessary to make any judgments how good data collection worked. Anyway, there seems to be consensus that much thought has to be given on how to optimise data collection. This is also an ethical question as participants time would be wasted if data were severely compromised. According to Jennet (2016) contributors do care much about the quality of data.

There are also some open questions about how to evaluate the issue: To do justice to citizen science, it would be necessary to assess the quality of data provided by traditional research with the same evaluation concepts and rigour instead of using them as a reference for the quality of data that were collected by lay persons (e.g. Specht & Lewandowski, 2018).

### *Some forms of citizen science raise people's interest in science and innovation*

One can assume that this is closely connected to the quality of the conducted research. While it is widely assumed that citizen science raises the interest in science and innovation, one could also raise the question under which conditions it does so and if a suboptimal project could have a detrimental effect.

## Discussions on ethical issues and caveats

There seems to be not enough awareness among citizen science proponents what a broad range of meanings is given to the term citizen science presently. Hence, one sees it still depicted as a means to achieve very different things at the same time. In Nascimento et al. (2018), for instance, citizen science provides not only a huge amount of data, it supports better policies, empowers citizens, educates them about science, and much more. The only challenge they see is an assumed resistance of researchers against introducing more citizen science (Nascimento et al. 2018, p. 219 et seq.)

Not only are there generalisations about benefits of citizen science to be expected that do not heed that the different forms it can take can hardly be comparable on the benefit-dimension; in the same way generalising statements about the lay people involved are made, which are not supported by empirical research.

> *Citizen scientists show significant commitment to the topic and are as capable as the best researchers in many cases. Thus, the information that they produce should be trusted.* (Haklay, 2013, p. 115)

This general statement could be misunderstood as a call for a too mild assessment of research or data provided by whoever is called or calls him-/herself "citizen scientist". It demands a level of trust for a group of frequently unknown persons that many scholars and most critical citizens would deny anybody else, including professional scientists. If critical evaluation and doubt have always been an important corrective in research and innovation, why should any participants in citizen science, be it professional or lay researchers, exempted from scrutiny? (Additionally, it implicates that earning trust would mostly be a question of capabilities, without mentioning other and maybe more important factors like accountability.)

**A narrative of hostility against citizen science**

In parts of the citizen science communities, there exists a narrative that there is general resistance from traditional scientists to citizen science (e.g. Nascimento et al., 2018). Haklay perceives an elitism among professionals which he makes responsible for mainstream science not taking seriously the results produced by citizen science (Haklay, 2013). Admittedly, there may be scientists who frown upon "ordinary" people "playing being a scientist". And there are quite a few examples that show how established researchers try to fend off results from citizen science projects on the grounds that lay persons were involved. For example, the numbers of the mothers who measured radioactivity levels after the Fukushima disaster in 2011 were dismissed as the non-scientific work of irrational women who spread rumours about hazards (Kimura, 2016). However, we did not find any systematic studies that investigated if a principally negative attitude towards citizen science is wide-spread among the majority of credentialed scientists nowadays or if we are observing relatively few isolated cases. There are some aspects to be considered. Scientists do not have a reputation of being extraordinarily fair to each other. Research shows that high competition makes the field prone to conflicts. (e. g. Twale & DeLuca, 2008). Why should scientists treat citizen scientists better than their colleagues? Another argument for citizen science not being taken seriously would be the observation that a researcher who engages in citizen science has lower chances to make a career. At least, several citizen science proponents demand that the traditional academic reward systems need a change to make citizen science attractive to researchers (e. g. Schade et al., 2021). But this might not be related specifically to engaging in citizen science: A researcher who puts energy in anything else than building a career has little chances to climb the ladder of the academic hierarchy. Science is a rather fierce working environment (Hesli & Lee, 2013; Gill, 2016; Salminen-Karlsson, 2018; Carpintero & Ramos, 2018). As long as a researcher has not found a stable working position ("tenure track"), s/he lives under precarious conditions that forces her/him to constantly hunt after publications, opportunities to present at conferences, applying for funds and to elbow out competition. Also, researchers who invest in teaching students or who take a sabbatical, care for family, etc. experience disadvantages for their careers. Experts see this as a reason for not enough people taking up science careers, which might create a barrier to the development of a knowledge society. Hence, there are efforts to make the working places more agreeable and flexible to attract young people and women. In this bigger picture the fault lies not so much in citizen science not being taken seriously enough, but in creating working places that allow scientists to have a life beside their profession.

Additionally, not all research results are taken seriously, be they mainstream or citizen science. As far as publications are concerned, in some disciplines an abundance of low-quality preprints is deplored by many scholars and quite a few attempts to publish "mainstream research" are rejected by high impact journals. For instance, an actual example provides Añazco et al. (2021) by reporting that out of their sample of 5,061 preprints dealing with the COVID-19-crisis only 288 were published, which equals a publication rate of 5.7%. The authors consider that more publications of preprints will follow, but the percentage remains still very low. (Añazco et al. 2021, p. 4 et seq.) It would be a research project of its own to investigate further, but it suffices to say that for any given project one cannot assume that it would have been published if it had been carried out by professionals only. Additionally, citizen scientists frequently carry out tasks that have never been carried out by professionals only. Data collection, taking probes and other assistive work has also been done by employed non-professionals, which to our best knowledge does not cause a rejection of research results by academia. There could be other reasons for results being less visible in literature: One could ask if the type of research taken up by citizen science may be less likely to be published, because citizen scientists are usually not under any pressure to choose well-publishable topics. The reason for lower publication rates of research done by citizen scientists would deserve investigation as well as the attitudes towards citizen science within the different disciplinary communities.

### Discussion about ethical and integrity issues in citizen science

Rasmussen and Cooper (2019) begin their editorial on ethics in citizen science with justifying why the topics deserves immediate attention:

> *Because scientists and citizen science practitioners are humans, and because humans err (or worse), we should expect that problems in the field will arise. We should not wait for a problem to bring ethics to the door of citizen science and react to it then; instead, we should find and prospectively address potential problems. (*Rasmussen & Cooper, 2019, p1)

Concerning the potential benefits of citizen science, there is relatively wide-spread optimism in the literature. However, some pitfalls or barriers are brought forward by scholars that (can) hamper its hoped-for benefits or turn them even into disadvantages for society at large or for some social groups.

**Power imbalance** is an issue that is frequently brought forward by citizen science scholars. According to this narrative, it could lead to an exploitation of citizen scientists by professionals, condescending attitudes, lack of recognition and insufficient respect (Keune, 2019).

But it is an open question whether it is realistic to always assume a hierarchy that allows for condescension or exploitation. Firstly, in reference to what is known about lay participants (see Chapter 5.3.2), there is some indication that they are mostly well-educated and do not usually belong to underprivileged groups. This is not surprising because being able to volunteer requires resources. Time resources are not available in abundance to the less affluent, quite on the contrary. The lone parents or people struggling with survival have little time to spare.

Secondly, as far as citizen scientists are volunteering without any direct or indirect pressure. They most likely will simply stop participating in the respective project if dissatisfied. Research on volunteering in the non-for-profit-sector in general shows a high demand and competition for volunteers, their unpaid work is an important resource for NPOs, their recruitment and retention are an important topic (see e. g. Garner et al., 2011; Randle et al, 2013; West & Patemen, 2016; Butt et al., 2017; Marsh & Cosentino, 2019; Waters & Bortree, 2012). There is rather a shortage of volunteers. "Exploitation" suggests that the exploited party is weaker, has a lower social status and thus can be exploited by the stronger party. However, the opposite is equally possible, namely that many fully voluntary citizen scientists – or some of them – could be enjoying a higher social status than the professional researchers. Depicting citizen scientists in general as potential victims is problematic, not only because it is another deficit model. There is not enough research about the socio-economic and educational background of participants, but a dominance of middle to upper class members is widely agreed on (see Chapter 5.3). A high social status not only lowers the risk of being exploited, but also the question appears, why it would be desirable to give privileged social groups the power to influence science in most steps of the research process. This contradiction would merit much more awareness than we found in literature.

Exploitation could be a very realistic scenario if citizen scientists are members of vulnerable groups, have low socio-economic status and/or experience (indirect) pressure to participate. This issue would deserve additional research: Because not much is known about participants in citizen science and their motivations, there could be a lot of blind spots. For instance, economic and political power relations in communities or simple group dynamics could be strong enough to discourage nonparticipation. Another field where full voluntariness cannot be guaranteed, is citizen science in the scope of formal education. Even in cases where students are given a choice there might be indirect sanctions for those who refrain from participating in offered citizen science activities. And in professional life especially young people have to fill their curricula with all kinds of unpaid work (see e. g. Holdsworth, 2017; Curiale, 2009; Howker & Malik, 2013; Stewart & Owens, 2013,) to increase their chances on the labour market (Spera et al., 2013)

Some authors give examples where paid employees have been successively replaced by unpaid, voluntary workers (e.g. Woolley et al., 2017). The question whether this elimination of jobs is the cause or the consequence of voluntary work needs careful investigation. It leads to the question how far a citizen science activity benefits the common good (however defined) or how far somebody could draw economic gain from the unpaid work of "citizen scientists", either in the short or in the long run. It should go beyond the most obvious cases where enterprises are involved who have a reputation of exploiting labour force, but one would also have to investigate how far it could be an unintended side effect of successful volunteering, if the unpaid get into rivalry with the employment opportunities of others. And more importantly, how such undesirable impacts could be avoided.

Several authors point out risks of breaching privacy and data protection.

**Incomplete information**, **unclear communication or** any **lack of transparency** can deceive a participant, intentionally or by neglect. It can make participation a disagreeable experience for citizen scientists. Making sure that all necessary information is communicated clearly is crucial, including the impact the results of the conducted research by citizens scientists can have.

Pocock et al. (2020) examine using citizen science for the detection of invasive species which afflict trees. One ethical dilemma they see is citizen scientists being taken by surprise when trees are felled, because they expected other solutions, like actually saving the diseased trees. (Pocock et al., p. 723 et seq.)

> *Good communication is required because people who could be effective early detectors may be dissuaded from reporting due to their concerns about the impacts of eradication measures, both to methods used (e.g., insecticides or culling mammals) or their outcome (felling trees or restricting recreational access). (Pocock et al., 2020, p. 725)*

While several authors scrutinise project holders for potential misconduct, only few authors discuss possible imperfections or faults that could be found on the side of the citizen scientists, and how to deal with them. Citizen scientists are only humans after all, but parts of the citizen science communities make generalising positive assertions about their abilities and characteristics.

**Conflicts of interest and the claim of the democratisation of science by citizen science**

A Nature editorial in August 2015 applauds the achievements of citizen science but ends with raising concern especially whether it should influence policies:

> *Scientists and funders are right to encourage the shift from passive citizen science — number crunching — to more-active roles, including sample collection. But as increased scrutiny falls on the reliability of the work of professional scientists, full transparency about the motives and ambitions of amateurs is essential.* (Nature, 2015)

The following discussion shows that parts of the citizen science communities are rather sensitive to critical standpoints: The citizen science community reacts strongly and defensively. On the ECSA website we find a letter to the editorial that was reposted from the CSA website:

> *However, instead of seeing public engagement with citizen science as an asset – one that channels public concerns into asking targeted questions and obtaining sound scientific evidence – the editorial saw this as cause for concern and conflict of interest.*
>
> *Traditional science also struggles with issues related to transparency of motives, conflict of interest, and integrity. Citizen science is not special in this regard, but*

*by singling it out, the Nature editorial casts undeserved doubt upon the integrity of citizen science data.* (ECSA Website)[12]

But how does this make the concern raised by the Nature editorial invalid? Without taking sides concerning the examples the editorial gives, the question is legitimate: If traditional science has problems with managing conflicts of interest, why should citizen science be exempted? Although most researchers are aware that fully neutral science is seldom achievable, the full transparency for which the editors advocate, is no unreasonable demand – neither for traditional science nor for citizen science. That individual interests can be "channelled" into research questions is idealising public participation, irrespectively if this is done in science or any other fields where decisions are negotiated.

In their answer to the Nature editors some highly ranking citizen science proponents frame citizen science as a political tool, because it "*channels public concerns into asking targeted questions and obtaining sound scientific evidence*" (ECSA, 2016). This claim would only hold true if citizen science would be able to involve all members of the public, which it never does. Instead, only small publics participate in a certain activity. Such a group of individuals cannot be regarded as "the public" or society as a whole.

The claim that citizen science would democratise science is one that appears frequently in literature. It is also postulated in ECSA's 10 principles of citizen science:

*However, unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratization of science.* (Robinson et al., 2018, p. 29)

Public engagement in science is not some kind of panacea to "democratise science". The highly contested Flint Water Crisis shows how difficult it is to evaluate the potentials and pitfalls of citizens engaging in science on their own behalf. In 2014 and due to a construction project, the city of Flint switched the water supply temporarily to a new source. Soon after, residents began to complain about skin rashes, hair loss and other health conditions. Residents organised sufficient evidence that the water was contaminated with lead, other toxins and pathogens, The municipality ignored the complains for months and insisted that the water was safe, but eventually was forced to switch back to the original water supplier, to repair corroded water pipes and to offer compensations to the inhabitants.

The case is still highly contested, a case of highly successful citizen science for the one, a case of citizen science going wrong to the others. While some scholars emphasise how the citizens partnered up with scientists to prove their cause, others paint a picture of citizen science going array after a good start, with an enterprise-affiliated NPO selling products and citizens forging evidence to increase compensation (see, e. g., Roy & Edwards, 2019; Pauli, 2020; Ruckert et al., 2019). It seems impossible to judge what really happened in retrospect. Politicians, citizens or credentialed scientists witnessing the crisis were too involved to be regarded as a fairly objective source of information. Maybe this opens the question if at some point, after citizens have collected evidence, in cases where so much is at stake, it would be good to bring in experts that are trusted by all parties.

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[12] https://ecsa.citizen-science.net/2016/05/25/citizen-science-community-responds-to-nature-editorial/. Last visit on 12. 2. 2020

**Giving a say to whom and why in developing research policies or projects?**

In cases where public engagement influences research policies, citizen science certainly is a political endeavour. There is some consensus among scholars that in the majority of projects participants contribute free labour force but are not involved in decision making. If that is true, it means that in citizen science (see Chapter 5), in spite of all claims, there is relatively little experience with what some refer to as "democratising science" as it is not usually claimed for data collection activities without decision making power of citizen scientists.

Science and innovations are not the only fields in which the participation of citizens is expected to improve democracy. In debates about citizens' deliberation in general, topics emerge that slowly find their way into the debates on citizen science.

Scholars believe that citizen science participation is biased towards well-educated, male, middle-class members of advanced economies (Haklay, 2013, p. 112; Strasser, 2019, p. 62-63). In many projects it remains unknown who actually participates. Obviously, it contradicts some ideals that are important to the citizen science communities, such as "democratising science" and the egalitarian approach.

Nevertheless, the demand to give citizens or the public engaging in science more power is wide-spread. It is mirrored in categorisations that build on measuring the quality of citizen science by the extent to which participants can influence the research project.

In 1997 Hartman criticised Earthwatch, a global CSO that organizes eco-tourism, for not sufficiently involving the lay contributors in the research process:

> *"We could partially interpret Earthwatch as an organization in which the public is excluded (administratively and cognitively) during the creation of research objectives, pays to be 'utilized' during the data-collection stage, and is then once again (cognitively) excluded during the reporting of results through publication stage"* (Hartman, 1997, p. 84)

Earthwatch organizes research expeditions for which citizens pay themselves. Such travels cannot be afforded by everybody, and this probably leads to a high selectivity for wealthier participants. Demanding that these citizens should have the power to co-determine the goals and design of research amounts to demanding that those who can afford it should be allowed to buy themselves into science.

That citizen scientists should have political power sometimes appears as an unquestioned premise in literature:

> *With the advent of the Internet, citizen science is experiencing an explosion in growth, but it is not impacting conservation decision-making to its full potential. Now is the time to address this issue while we are still in the exploration and development phase of this newly reborn phenomenon.* (Newman et al., 2016, p. 9)

Advocating for citizen science to impact directly on policies might be caused by an overestimation of its democratic potential. There are voices warning against idealising participatory approaches and asking for caution. For instance, the heritage expert Harald Fredheim (2018) states that

> *Similar to that of social innovation (Olma 2016), part of the appeal of participatory approaches is the promise of circumnavigating politics and*

> *existing power structures. It should, however, be clear that this is not possible; participation merely creates new arenas for power to be negotiated.* (Fredheim, 2018, p. 625)

There is another fundamental problem, when citizen science claims to make science more democratic. When citizens are volunteers, their possibilities to participate depends on their resources. Time that is not needed to work for a living or to cut down living costs is a luxury the poor not often possess. Although not sufficient research on citizen science participants is available, there is some indication that the majority of them are relatively well off. Volunteering participants might be mostly well-educated members of the upper and upper middle class (see Chapter 5.3). Hence, contrary to the egalitarian goals, the chances to participate are not distributed equally among citizens. As long as citizen science is about contributing unpaid work for the common good (however defined) this is in line with other caritative activities where the wealthier are asked to donate some of their better resources. But if the more affluent get a better chance to deliberate and prepare decisions, this is quite a different matter.

Scholars and practitioners talking about engagement of "the public" in other contexts than science see several issues that challenge the assumption that giving citizens a say would per se improve democracy in decision making:

NIMBY (Not in my backyard) and LULU (locally unwanted land use) are well-known catchwords in urban planning. If we assume that the wealthier have better chances to fend off power plants, chemical industries or waste disposal facilities, they may often be realised in poorer neighbourhoods, where citizens have less time and other resources to organise resistance. If citizen science is supposed to lead to political decisions, as it is framed by some scholars and/or practitioners, then personal motivations and potential conflicts of interest would merit more attention.

Sometimes not single citizens but non-profit organisations are partners of professional researchers in citizen science projects. The term NPO is very broad, and it is not a term that guarantees grassroot engagement. Individuals, enterprises or even government bodies can establish NPOs. NPOs can establish umbrella NPOs. NPOs can be affiliated to companies, political parties, religious and other groups or influenced by them.

In the field of health and medicine, the possible conflict of interest that derives from pharmaceutical industry sponsoring **patient advocacy groups** is most obvious. There has been even evidence for Big Pharma encouraging people with certain health issues to start such initiatives. It has been discussed for many years how the producers of medication influence patient advocacy groups who are important partners who can powerfully lobby products when meeting policy makers. Meanwhile, US, European and Australian associations have set up codes of conduct to safeguard any patient advocacy group against too much influence from one pharmaceutical company. Nevertheless, as Karas et al. (2019) explain, the rules are not very binding and a breach is hardly followed by sanctions (Karas et al., 2019). Khabsa et al. (2020) ran a meta-analysis of studies on financial relationships between patient and consumer representatives with the health industry. They come to the conclusion that such relations are variable but frequent and that there is a lack of transparency. Because they can create conflicts of interests in patient representatives and groups, they recommend that research and policy introduce rigorous regulations to disclose such links and - if possible - to open other funding resources for patient groups (Khabsa et al., 2020).

In medicine, we find more discussion among scholars on ethical issues than in some other fields. This is not surprising, because the health sector is under stricter societal and governmental observation (e. g. Fiske et al., 2019; Wiggins & Wilbanks, 2019) and potential harm can be more severe and also more obvious.

### The well-discussed topic of recognition in citizen science

The literature also often deplores a possible **lack of recognition** of citizen scientists, which is mostly expressed by not naming (all) those who contributed (Smith et al., 2019; Houllier & Merilhou-Goudard, 2016).

How far this is an issue probably depends on the characteristics of a project and how much was contributed by the non-professional participants: If somebody who has invested considerable time and thought, has discovered or invented something, stealing the laurels is a serious issue. Attempts to claim credit for the results of these efforts may even have legal consequences. An appropriation of the intellectual work of others is also against the European Code of Conduct for Research Integrity (ALLEA, 2017), which does not state that this rule would only apply if the injured person is another scientist. On the other hand, if thousands of persons have sacrificed only a few minutes of their life time for data collection, they probably neither expect nor insist on receiving "recognition". Many may not even wish to be named as an individual. (It would be also interesting to have investigated, if the issue of recognition has really such priority for citizen scientists as it has for academics for whom an impressive publication record is necessary for making a career in a highly competitive environment. Being free of this treadmill might be an advantage.) The issue of naming contributors is a highly complex one: As Cooper et al. (2019) point out, giving the names of contributors contradicts confidentiality. It is not only but especially critical in what Cooper at al. (2019) call type 2 projects, in which volunteers not only do research (or related tasks) but at the same time function as research subjects and thus feed personal data into the projects (Cooper et al., 2019).

### Guidelines for ethical issues in citizen science?

When Cooper et al. (2019) conducted a preliminary assessment of ethics oversight, they investigated what they termed type 4 project in their categorisation (see Chapter 6): Projects in which volunteers do not cooperate as subjects of research but as active participants conducting research or related tasks. The authors examined 47 projects from 38 platforms and they found out that 20 projects and 19 platforms provided neither an equivalent to Informed Consent nor Terms of Service and only 2 projects offered Informed Consent (Cooper et al., 2019, p. 4). They conclude that whereas there exist rules and regulations for protecting the rights of lay persons who participate in research in the role of research subjects, almost no regulations are in place for volunteers who conduct research or related tasks and cooperate with professionals from research institutions. The authors compare the risks for lay researchers to the risks for human subjects of research and show that although there are differences, both groups could suffer physically, psychologically, on a socio-economic level and/or by a loss of confidentiality:

**Table 1:** The typical risks tend to be different for conventional human subjects than for volunteers in Type 4 citizen science projects.

| Conventional HSR | Volunteer in Type 4 project |
|---|---|
| **Physical risks** | |
| Discomfort<br>Pain<br>Injury | Manipulation from persuasive technology<br>Risk of harm from data gathering activities |
| **Psychological risks** | |
| Anxiety<br>Sleep deprivation<br>Depression | Loss of efficacy by not having access to research data<br>Distress from not having acknowledgement of contribution |
| **Social/economic risks** | |
| Embarrassment<br>Loss of respect<br>Loss of wages | Justice by not having access to benefits of volunteering<br>Intellectual property loss while solving problems and sharing ideas |
| **Loss of confidentiality** | |
| Invasion of privacy<br>Loss of dignity | Loss of geo-privacy when gathering data |

(Cooper et al., 2019, p. 69)

Cooper et al. (2019) advocate for making lay participants strongly aware of privacy and confidentiality risks and potential legal liabilities towards others. For this reason, they suggest that projects insure volunteers against such risks where they could emerge (Cooper et al., 2019, p. 5).

Only recently, a group of researchers from ETH Zürich, Jobin et al. (2020), wrote recommendations for the *Competence Center Citizen Science* (CCCS) at their university. Building on the categorisation of Cooper et al. (2019) they analysed the ethics guidelines and ethical principles from the Citizen Science Association (CSA), the European Citizen Science Association (ECSA), Bürger schaffen Wissen (GEWISS), Österreich forscht and DIYbio.org. For the CSA, where they found references to external sources, they analysed the Belleville Committee Ethical Principles, the CCPH Guiding Principles of Partnership, and the Beyond Sabor Code of Ethics. Jobin et al. (2020) found out that the ethical issues and the questions of oversight in citizen science are underdeveloped.

**Citizen science - a neoliberal plot?**

In his thought-provoking essay "Against Citizen Science" Philip Mirowski (2017) radically criticizes citizen science as styling itself as a grassroot movement fostering the common good but really rooted in market fundamentalism that one might call neoliberalism. He paints a grim picture in which citizen science benefits mostly particular economic interests who harvest the data and unpaid work provided by citizens, who replace employed professionals and in which science gets privatised and governed by market forces, while policy makers delegate responsibilities. One can hardly refute his claim that much of what is labelled as citizen science looks more like a top-down enterprise than a bottom-up movement.

> *However, let's look at who's behind a sample of recent initiatives: the National Science Foundation in the United States, which funded the PBS series The Crowd & the Cloud (2017); US congress, which passed enabling legislation for citizen science in the American Innovation and Competitiveness Act (AICA) (2017);*

*the Pentagon's DARPA, which donated $10 million after 2012 to introduce biohacker spaces in more than 1,000 high schools; an NGO called the European Citizen Science Association; and various foundations with deep pockets dedicated to something called open science. Not much space left for the average Joe. Indeed, the 'citizen' herself seems almost entirely absent from this crowded phalanx of bureaucratic programmes and entrepreneurial interventions, all united in their fervour to found a republic in which citizen science can flourish.* (Mirowski, 2017)

From different fields we hear voices being aware of the risk of approbation of participatory approaches by particular interests. From the field of cultural heritage Fredheim (2018) says:

*Due to neoliberalism's penchant for masking its capitalistic and deregulatory intentions in a rhetoric of freedom, democratisation and innovation, and its incredible success in doing so through domineering economic disruptions like the 'sharing economy', heritage professionals, scholars and volunteers would do well to be wary of new 'democratising' initiatives intended to double as relief for pressurised institutional budgets.* (Fredheim, 2018, p. 620)

And also Vohland et al. (2019) discuss if citizen science might support neoliberalism by providing a cheap workforce. They come to the conclusion that citizen science can either support or counteract neoliberal developments. They acknowledge the potential of exploitation of citizens' cheap labour by state or economy, but they also hope that citizen science would increase social cohesion and sustainability by mutual learning and help to maintain a "non-economic sphere." They recommend self-reflection and developing ethical standards to safeguard citizen science against being used by neoliberal trends:

*To avoid instrumentalization by the state or companies, to ensure fair interactions with participants, and to keep a space free of the economization of life, we offer recommendations that begin with the call to be self-reflective, and to develop an international ethics of citizen science. For this, the citizen science community must analyse its impact, normative foundation, and practices.* (Vohland et al., 2019, p. 8)

## 5.3 People involved in citizen science

### 5.3.1 Participation patterns

*Marinos Anastasakis & Kathy Kikis-Papadakis*

In studying the characteristics of people engaging in citizen science projects, one may follow the simple approach of classifying participants according to their *demographic characteristics* (e.g., age, gender, race, ethnicity, socioeconomic status) and their *participation patterns* (e.g., how many hours a user spends on a project). Consequently, the review of the literature concerning is divided into two sections, demographics and participation patterns.

### 5.3.2 Demographics

A large part of the literature reporting on participant demographics deals with projects situated in North America. These studies have found that citizen science participants are mainly white, middle-aged and well-educated males. For example, the US National Academies of Sciences, Engineering and Medicine[13] conducted a meta-analysis of 68 citizen science projects in order to explore participant demographics (Pandya & Dibner, 2018). The data used for the study cover a period from 2000 until 2018 and are mostly related to outdoors projects (80%) situated in the United States (74%). The meta-analysis results showed that citizen science participants are mainly white, middle-aged (21-60) and well-educated males, with a slight tendency to have previously participated in other projects as well. Similar findings have been also reported by Burgess et al. (2017). In their study, Burgess and colleagues surveyed managers from 125 different citizen science projects on biodiversity and found that participants are primarily white, well-educated adults with no bias in gender. The majority of these projects were housed in North America (66.4%), followed by projects housed in Europe (9%) and Asia (2.5%).

Despite the potential differences that may or not exist between projects housed in different geographical regions, similar demographics have been also reported by many other studies as well (cf. Merenlender et al., 2016; Price & Lee, 2013; West & Pateman, 2016). For example, Mac Domhnaill et al. (2020) surveyed 438 adult citizen scientists on biodiversity in Ireland and found that participants are middle-aged, highly educated, employed and financially independent people residing in rural areas. Based on their analysis, they concluded that certain populations such as younger people, people residing in urban areas, that are unemployed or have lower levels of education are underrepresented in their study.

Not knowing to what extent younger people i.e. primary and secondary students participate in citizen science projects is a concern that has been raised by a few authors (Herodotou et al., 2020; Mac Domhnaill et al., 2020; Pandya & Dibner, 2018). Despite that, investigating demographics of student populations has been realised by an extremely limited number of studies: to our best knowledge, Herodotou et al. (2020) is the only study investigating younger people's demographics. Herodotou and colleagues studied a sample of 104 young participants about their online engagement in various Zooniverse projects related to the Natural History Museum of London (Project Plumage, Science Gossip, Notes from Nature, London Bird Records, Orchid Observers and Penguin Watch). Although their target group was indeed young people (10-19 years old), the majority of participants in their sample was found to be females (67%) something contradicting findings from the wider citizen science literature where most of the participants are found to be males. In explaining this gender imbalance, Herodotou et al. (2020) suggest that within youth populations, citizen science participants may be predominantly females or it may be the case that females are more inclined to be engaged in Zooniverse projects (although as the authors note larger samples are needed to confirm this).

The absence of adequate data regarding participant demographics limits not only our ability in drawing concrete conclusions about who participates in citizen science projects but also in attending issues related to equity, diversity and inclusion[14]. In their

[13] www.nationalacademies.org

[14] According to the National Academies of Sciences, Engineering and Medicine (Pandya & Dibner, 2018), equity refers to the distribution of opportunities enabling participants to engage

report for the National Academies of Sciences, Engineering and Medicine, Pandya and Dibner (2018) concluded that:

There is limited systematic, cumulative information about who participates in citizen science. Community and youth projects are underrepresented in the available data, suggesting that existing data is biased toward white middle- and upper-class populations. (p.145)

If certain ethnic, racial or socioeconomic groups are indeed underrepresented, it is less likely for them to benefit from citizen science (Evans et al., 2005) and since many citizen science projects aim at motivating participants in pursuing scientific careers, a reduced diversity of citizen science volunteers may result a less diverse scientific workforce (Pandya, 2012).

In sum, the literature exploring participant demographics demonstrates a few areas that merit further research. First, certain groups such as young people (i.e., students) or people with lower levels of education are currently underrepresented in citizen science projects. Second, it is currently unknown whether a project's scientific area is related or not to participant demographics (e.g., whether astronomy related projects attract more well-educated, white males). A final remark relates to studies exploring students' demographics. Although this line of research is currently limited, results from projects with students contradict insights provided by other studies: for example, Herodotou et al.'s (2020) findings show that in contrast with the general consensus (participants are mainly males), in citizen science projects with students the majority of volunteers are females. Despite that, there is no sufficient evidence in concluding that demographics in citizen science projects with students follow a different pattern than with projects entailing adults.

### 5.3.3 Participation patterns

Due to their nature, online citizen science projects lend themselves in allowing us to study volunteers' usage patterns in an unobtrusive manner. Although, studying the motivational aspects of engagement, i.e., ***why*** a person chooses to engage in a citizen science project, has a well-established literature, our understanding of ***how*** participants actually engage in a citizen science is still under development (Ponciano & Brasileiro, 2014).

Perhaps the most widely used notion for studying how a participant interacts with a citizen science project is ***engagement***. According to Ponciano and Brasileiro (2014) "engagement means to participate in any enterprise by self-investing personal resources, such as time, physical energy, and cognitive power" (p.4). Herodotou et al. (2020) note that within the broader Human Computer Interaction (HCI) literature, engagement has been conceptualised "on a continuum based on the type of activities that users engage with and the intellectual contribution required" (p.2).

Typical measures of engagement include *frequency* (the number of days a volunteer contributes); *activity ratio* (the proportion of days on which a volunteer was active and made at least one contribution in relation to the total number of days he/she is linked to the project); *typical session duration* (the continuous period of time a volunteer devoted in making a contribution), *daily productivity* (the average number

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in a successful manner, diversity relates to the demographic differences among individuals, whereas inclusion focusses on the processes that make participants feeling welcome.

of contributions per day), *daily devoted time* (the average number of hours a volunteer contributed to the project on days he/she was active) (Herodotou et al., 2020; Ponciano & Brasileiro, 2014; Ponciano et al., 2014).

A good starting point in understanding how participants engage in citizen science projects is Ponciano et al.'s (2014) work. Ponciano and colleagues classified roughly 23,000 participants from two Zooniverse projects (Galaxy Zoo, Milky Way) into ***transient*** and ***regular***. Transient volunteers are users that complete tasks only one day and do not return, whereas as regular volunteers are characterised those who return and make contributions at least one more day. Similar results were also reported by Eveleigh et al. (2014). Eveleigh et al. studied the behaviour of 299 volunteers (aged between 26-79 years) from the Old Weather project. By analysing each participant's total number of contributions, forum posts and days spent on the project, the team distinguished two groups of participants: ***high contributors***, referring to users demonstrating regular and significant participation and ***low contributors*** referring to participants with small input and little involvement in the project.

In obtaining a more detailed understanding of participants behavioural patterns in citizen science, other studies have utilised a larger number of engagement descriptors such as activity ratio, relative activity duration and daily devoted time. This is an approach taken by Ponciano and Brasileiro (2014) and Herodotou et al. (2020). Ponciano and Brasileiro (2014) studied approximately 30,000 volunteers from two projects (Galaxy Zoo, Milky Way). By performing a cluster analysis Ponciano and Brasileiro distinguished five groups of participant engagement: (1) ***hardworking***, referring to volunteers exhibiting hard work but leaving early the project; (2) ***spasmodic***, applying to participants making contributions for a short period of time and with irregular periodicity; (3) ***persistent***, concerning volunteers who remain linked to a project for a long time but are active for a few days only; (4) ***lasting***, referring to volunteers sharing similarities with the persistent profile yet they remain linked to a project for a shorter period of time and; (5) ***moderate***, referring to participants not being particularly distinguishable from the other profiles except that they demonstrate a reverse relationship between engagement and days being active (being less days linked to a project translates to more contributions).

By performing a cluster analysis, on 104 young people (between 10-19 years old) participating in various Zooniverse projects, Herodotou et al. (2020) identified the presence of five distinct engagement profiles: (1) ***systematic users*** (*N*=5, active users who visit the platform regularly); (2) ***casual users*** (*N*=8, not very active users who demonstrate very inconstant visits); (3) ***moderate users*** (*N*=16, not very active users who have constant visits); (4) ***lasting users*** (*N*=40, users that although have few active days and do not visit regularly a projects, they are linked to Zooniverse the longest) and; (5) ***visitors*** (*N*=34, users that although contribute to a project for only a few days, they demonstrate high levels of activity during those days).

In sum, we can conceptualise engagement patterns in citizen science projects as a continuum with two extreme poles; on the one end we find users who interact once and then leave the project (low contributors, transient users, visitors) and on the other we find volunteers contributing regularly (high contributors, regular users, systematic users). In between these extreme profiles we find a spectrum of different engagement behaviours depending on the metrics and analytical approach used in classifying them. Although the literature suggests that some profiles may have a universal character with no differences between adult and young populations (lasting and moderate users), young volunteers exhibit distinct engagement patterns when compared with adults (Herodotou et al., 2020). Thus, as mentioned in the case of participant demographics, more research is needed in terms of exploring behavioural patterns among young volunteers.

### 5.3.4 Enablers, barriers, incentives, disincentives for the mainly involved persons

*Emilia Lampi, Joni Lämsä & Raija Hämäläinen*

With the global changes in citizen science brought about by the COVID-19 pandemic, a better understanding of the related enablers, barriers, incentives and disincentives has never been as important as it is today. Namely, we must be aware of the possibilities and challenges faced by various citizen science actors. This foundational work also allows us to pave the way for future research (see Work Packages 2, 3 and 4) in the area of citizen science by identifying connections between relevant studies that have yet to be uncovered (see the work plan of Work Package 4, specifically the triangulation of evidence; Maxwell, 2006). A search of citizen science alone in Google Scholar yielded approximately 71,000 results, illustrating the multi-layered nature of the topic. Researchers widely agree that involving citizens in research is beneficial for all participants, various disciplines, and society at large. Despite the vast number of publications on citizen science, current research has typically focused on the impact of individual projects, and only a few studies have investigated the impact of citizen science projects and public engagement in general.

To address this gap, we aimed to explore the understanding of citizen science based on representative studies of enablers, barriers, incentives and disincentives for the mainly involved people. We searched the Scopus database with a query string that included keywords related to our topic and identified the 10 most frequently cited citizen science reviews published in English. Three of these reviews were excluded as they did not explicitly state the enablers, barriers, incentives or disincentives of the people involved in citizen science. Since most of the reviews were published in scientific journals focused on biology and environmental sciences (Figure 1), we chose three illustrative examples from other scientific areas, such as sociology and education. Taking other fields into account is important as the enablers, barriers, incentives and disincentives might differ amongst the fields.

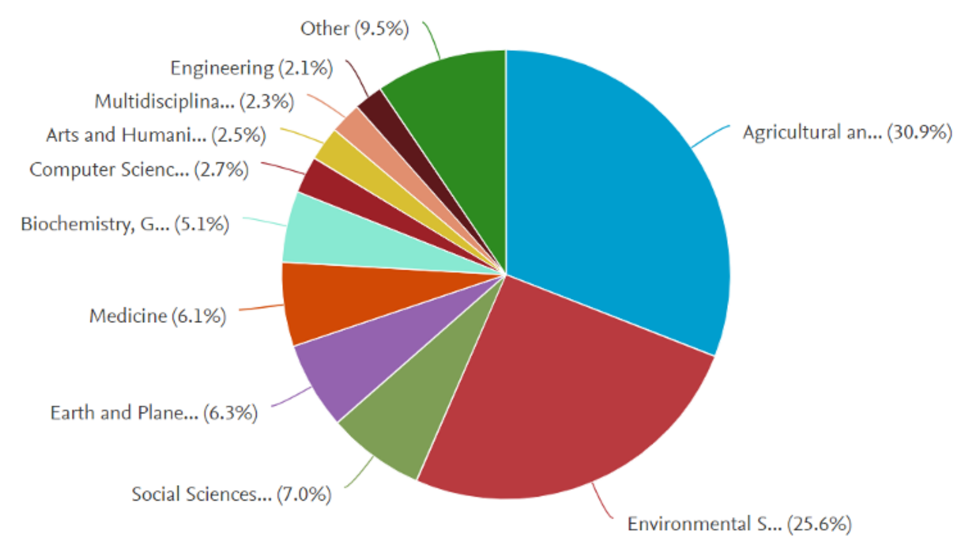


Figure 1: The thematic distribution of the reviews in Scopus

#### 5.3.4.1 Wide possibilities for professional researchers

Especially in the last two decades, the use of citizen science has rapidly increased in terms of scope and attention when professional scientists and policy-makers have noticed its potential at international, national and local levels (Liu et al., 2017). Utilising citizen participation can be a resource-wise opportunity to collect large, longitudinal datasets that could otherwise be difficult to acquire (Cohn, 2008; Danielsen et al., 2005; Tulloch et al., 2013). Technological developments allow researchers to reach out to a large number of citizens and provide effortless methods of communication and novel ways of collecting, analysing and/or discussing data with professional scientists and citizen scientists (Dickinson et al., 2012; Goodchild, 2007; Newman et al., 2012). Some researchers have noticed that, especially in the field of environmental sciences, engaging citizens in the research process will usually lead to practical actions and impacts in the local communities (Danielsen et al., 2005), stretching the research's benefits even further.

There are, however, concerns about data quality when non-professional researchers are involved (Bonney et al., 2009; Danielsen et al., 2005; Tulloch et al., 2013). It is crucial to design research projects carefully to avoid overly complicated tasks (Cohn, 2008) and oversimplified (Danielsen et al., 2005) or distorted (Newman et al., 2012) datasets. Furthermore, it is crucial to ensure that engaging in the research process will benefit the citizen scientists as well as the professional scientists (Cohn, 2008; Danielsen et al., 2005; Ramírez-Montoya & García-Peñalvo, 2018). This may mean ensuring that sufficient resources are allocated from the professional scientists' side for the coordination, training and constant support of the lay participants (Tulloch et al., 2013). All in all, a successful citizen science project needs very careful planning and sufficient resource investment, which might create barriers for some professional scientists.

#### 5.3.4.2 Multi-layered opportunities for participants

To maximise the benefits of citizen science projects for all involved parties, it is vital to understand why people would engage in citizen science—and why they would not. Citizen scientists can be driven by the opportunity to learn something new (Cohn, 2008; Dickinson et al., 2012; Newman et al., 2012), to do something meaningful by participating in scientific research (Cohn, 2008; Newman et al., 2012) or to contribute to social movements (McCormick et al., 2003). Other motivations include social reasons (Dickinson et al., 2012; Newman et al., 2012), altruism (Goodchild, 2007), competitiveness or monetary rewards (Newman et al., 2012) or the possibility of career benefits (Goodchild, 2007). Hence, the incentives are very diverse and multi-layered and might differ significantly based on the field, project type or culture.

The development of technology has been seen as a strong enabling and motivating factor for citizen scientists (Bonney et al., 2009; Dickinson et al., 2012). However, the increasing use of technology and the internationalisation of citizen science projects might also create barriers for those with limited internet access (Voinov et al., 2015) or limited language skills (Goodchild, 2007). Moreover, a major barrier or disincentive for citizen scientists may be tasks that demand certain competencies (Cohn, 2008) or are too difficult to conduct (Bonney et al., 2009). It is also vital that the costs of participating in citizen science projects not fall on the participants (Danielsen et al., 2005). Moreover, the participants must have a certain level of trust in the project for it to be successful (Voinov et al., 2015). Therefore, from the participant's perspective, careful planning and implementation of the project from the initiator's side plays a major role in creating accessible, motivating projects that benefit everyone involved.

The synthesis of the literature illustrates the diversity of citizen science projects and activities that makes it challenging to find common enables, barriers, incentives, and disincentives across the projects and activities. Instead, the different projects face different challenges when motivating the citizen scientists to participate in the citizen science activities. Altogether, there is indication from various examples but by far not enough evidence to make concluding remarks: more systematic research needs to be done in the future to come to conclusions.

### 5.3.5 Gender Aspects of Citizen Science

*Marinos Anastasakis, Kathy Kikis-Papadakis*

Given that citizen science has been linked by many scholars with the democratisation of science, reaching a wider range of audiences and participants should be consider a priority (Bonney et al., 2016). Our review regarding participant characteristics in citizen science has already shown that reaching more diverse participants in terms of their gender, age or socioeconomic status is certainly an area that calls for more attention and merits greater efforts if we wish to make citizen science more inclusive. Among the authors supporting that the gender dimension is not well articulated in the citizen science literature is Curtis (2018). In her literature review, Curtis identified 13 studies from 2005 until 2017 that report on participants' demographic data and concluded that typical participants in online SC projects are well-educated males with an interest in science or computing. Curtis notes that a range of ages have been recorded in these projects with no obvious trends but in some projects (e.g., involving distributed computations) participants tend to be younger. Despite that, our own observation is that the studies included in Curtis' review are primarily concerned with adults (mostly aged between 20 and 50). So, do the male-dominated participation patterns reported by many studies be related to a person's age? As mentioned earlier, not knowing to what extent primary and secondary students participate in citizen science projects is a concern that has been raised by a few authors (Herodotou et al., 2020; Mac Domhnaill et al., 2020; Pandya & Dibner, 2018). Thus, the fact that most studies report male biased samples might be related to participants' age: as noted before, Herodotou et al.'s (2020) study suggests that within youth populations, citizen science participants may be predominantly females.

A study offering a more in-depth account of gender differences in citizen science is the one by Cooper and Smith (2010). Cooper and Smith analysed data from participation in bird-related recreational activities in the USA and the UK. Data were categorised into four categories: supportive (membership in bird conservation organisations, *N*=1,095,346), participatory (citizen science projects, *N*=83,112), competitive (events or organisations that evaluate the quantity of birds reported, *N*=6,933) and authoritative (experts who often train and organise individuals in participatory activities, *N*=256). The participatory category included twelve citizen science projects. The sample from citizen science projects included only adults and was found to be slightly male biased (54.52%). When participants were examined on a per project basis, some citizen science projects were found to be female biased: these were not related to bird watching per se but to watching bird feeders, nest-monitoring etc. The authors suggest that these gender patterns may be related to constrains that female participants are imposed with or motivation differences with male participants. This is because when projects were categorised according to location (i.e., whether someone can participate by just being home or whether should go away), female participation occurs around their residence and male participation away from their residence. With regards to motivation, the authors suggest that female participants may be more motivated in helping birds, teaching children or assisting scientific endeavours whereas men may be more focussed on achievement.

Other authors have drawn attention to issues surrounding sampling procedure in the citizen science literature. For example, Füchslin et al. (2019) note that studies in citizen science are biased because they describe only people participating in citizen science projects who have additionally agreed to be surveyed. In an attempt to identify a wider and more inclusive group of people interested in citizen science, Füchslin et al. (2019) surveyed a sample of 1,051 people in Switzerland regarding their intentions of participating to scientific research projects. The survey results indicate that being younger, having a higher proximity to science or living in a household with children are significant predictors of participation in citizen science. However, their study showed also that gender, educational level or employment status cannot predict a person's interest in participating in scientific research.

An area of the literature that could possibly provide additional insights regarding the gender dimension in citizen science is related to projects where participation is primarily motivated by an interest in public safety or health. Examples include projects for reporting cycling safety data all over the world (Ferster et al., 2017) or identifying factors contributing to allergic rhinitis symptoms (Silver et al., 2020). Despite that, these types of citizen science projects are less common and the studies by Cooper and Smith (2010), Herodotou et al. (2020), Curtis (2018) and Füchslin et al. (2019) hint that gender, culture and age may be related to gender-science stereotypes. In this respect, Miller et al.'s (2018) work offer us great insights about the interplay of gender, age and culture. By conducting a meta-analysis of "draw-a-scientist" studies, Miller et al. found that stereotypes in science have changed during the last 5 decades, with more children associating women with science than in previous years. However, their meta-analysis also showed that as children age (around the age of 14-15), the tendency of associating women with science decreases and children tend to draw more male scientists. According to Miller et al. these results offer us an insight into how children respond to their cultural environment: one the one hand women's representation in science has increased during the last 50 years; on the other, children still learn to associate science with men because women remain underrepresented in some scientific areas.

## 5.4 Citizen Science and Education

### 5.4.1 Introduction

*Reuma De-Groot & Yaela Golumbic*

Research about the educational aspects of citizen science has been underway over the past years, alongside the rise of citizen science globally. Research has focused on individual learning outcomes in multiple projects, establishing typologies of learning outcomes and examining how these learning outcomes are produced and the processes involved (Ballard et al., 2017; Jordan et al., 2015; Phillips et al., 2018). Such research has taken place in relation to both formal and informal situations and spans learning in a variety of settings including schools and universities; science and nature clubs; museums and science centres; online communities and many more. While such research has developed greatly over the past years, a gap still exists integrating the knowledge about the educational benefits and its dynamics with the many citizen science settings.

### 5.4.2 Formal Education

*Patricia Santos, Miriam Calvera-Isabal, Reuma De-Groot & Yaela Golumbic*

Formal education refers to a "systematic, organized education model, structured and administered according to a given set of laws and norms, presenting a rather rigid curriculum as regards objectives, content and methodology" (Dib et al., 1988). The International Standard Classification of Education (ISCED) distinguishes eight levels of education but this research is only focused on Primary education (ISCED 1), Lower secondary education (ISCED 2) and Upper secondary education (ISCED 3) (European Commission/EACEA/Eurydice, 2018).

According to the European commission "knowledge of and about science are integral to preparing our population to be actively engaged and responsible citizens, creative and innovative, able to work collaboratively and fully aware of and conversant with the complex challenges facing society" (Hazelkorn et al., 2015). Moreover, as it is documented in literature, citizen science projects increase awareness and knowledge about the topics it addresses (Brossad et al. 2005; Evans et al. 2005; Jordan et al. 2011) besides giving the opportunity to participants in educating themselves in scientific thinking (Freitag A., 2013).

Teaching is a cooperative behaviour (Galef et al., 2005) similar to citizen science (Wiggins, 2011; Haklay, 2015; Cigliano et al., 2015; Heiss et al., 2017). In order to achieve the objectives and recommendations involving students through formal education, citizen science projects might "*provide a valuable way to mainstream science education and create a more balanced science-informed society*" (Hazelkorn, 2015).

Curricula in formal education are defined by mandatory subjects which contain basic contents for different fields of science organized by subjects, to obtain the same knowledge for all the students at the end of their mandatory education. This rigid structure improves students' knowledge on different subjects and sometimes drives them to discover their passions. Nevertheless, it could also provoke demotivation or not to be engaged in subjects which they are not interested in and of course it doesn't attend diversity (Jenkins, 2011 discusses what has been said about the issue so far).

Many educational strategies have been developed and institutionalized with the aim of improving learning or engaging students in science. Some examples can be found in the Open University innovation reports (e.g., Kukulska-Hulme et al., 2020). These annual reports propose to introduce citizen science as a part of the educational discipline using approaches such as the "citizen inquiry" (Sharples et al., 2013) or the "learning from the crowd" method (Sharples et al., 2016). Another example is the one proposed by the Institute for Research in Schools (IRIS[15]) which tries to promote participation in research allowing students to contribute to the scientific community.

The integration of citizen science into formal education provides a unique opportunity to increase the reach of citizen science beyond its typical audience of well-educated, affluent individuals (Ruiz-Mallen et al. 2016). Schools also provide a good setting for structured learning and can integrate citizen science into existing educational practices serving as facilitators and increasing student relatedness to science (Shah & Martinez, 2016). citizen science enables students to engage with hands-on, authentic and real-lire research while learning about science from multiple perspectives. Benefits of student participation in citizen science in school environments include self-efficacy for science and the environment; motivation for science and the environment; increased scientific knowledge; skills of science inquiry; and environmental stewardship (Phillips et al., 2018).

However, schools also place specific constraints on learning through citizen science with research highlighting the many challenges to learning in such settings. One of the main challenges as students are automatically enrolled in projects as part of a school task, is the absence of choice (Kelemen-Finan et al., 2018). This in turn can serve as the main barrier (and when given, enabler) for increasing student motivation and interest which consequently lead to self-determined learning.

An additional challenge is linking citizen science learning outcomes through to schools' strategic plan and standards-driven curriculum which need to allow space for real-life learning in scientific projects. (Jenkins, 2011). Fortunately, there is a growing recognition of this need within the citizen science community, with many projects identifying links to national curriculum and aligning project to address these requirements (Spicer et al., 2020). Indeed, providing teachers with ready-to-use material and lesson plans connected to school curricula has been shown to increase

[15] The institute for research in schools (IRIS): https://researchinschools.org/

teacher engagement and willingness to participate and facilitate student learning through citizen science (Bonney et al., 2016). Providing training which specifically addresses the needs of teachers as facilitators of citizen science can also contribute to their buy-in and involvement (Lorke et al., 2019).

Finally, in order to achieve high level learning outcomes, teachers have to be fully engaged and on-board with the project goals, methods and content. They have to view themselves as competent and in possession of appropriate skillsets to both facilitate project participation and student meaningful learning. To accomplish these, teachers have to abandon the classical approach of teaching science in which lecture and testing are strongly emphasized, and guide their students in making connections between the data, their community, and the environment (Jenkins, 2011).

Participation and engagement in citizen science projects through scientific inquiry promote scientific skills and learning benefits (Trumbull, 2000; Brossard et al., 2005; Bonney et al., 200; Cronje et al., 2011; Jordan et al., 2011; Wiggins, 2011; Herodotou et al., 2017; Redondo et al., 2018). Active contribution in citizen science projects also could change students' attitude and behaviour toward science or a specific topic (Brossard, D. et al. 2005, Ruiz-Mallén, I. et al. 2016). On the other hand, researchers benefit from students' participation building a community and generating knowledge about the research questions raised.

The common objective of citizen science projects is to conduct research in a specific field in order to answer a scientific question (Schäfer, T. et al. 2016). There is a wide variety of projects and topics (e.g., Zooniverse topics like space, nature, biology, humanities, etc. (Simpson, 2014; Pettibone, 2017) which means that citizen science offers an overview on science fields, and the opportunity to engage students into different and diverse topics and educational levels.

Although schools provide an environment explicitly designed for learning, not all the projects are designed for formal education or to involve children or youth (National Academies of Sciences, Engineering, and Medicine, 2018). Wiggings et al. (2011) defines a type of citizen science project as "Educational" that develops its activities educational-oriented. Others, nevertheless, adapt materials, practices and purposes for support learning outcomes (Ballard, et al., 2017, National Academies of Sciences, Engineering, and Medicine, 2018, Schuttler, S. G. et al. 2019).

To democratise science in the classroom (Bonney et al., 2016), the dialogue between scientists, teachers and students should be continuous. The role of scientists or coordinators is to assure the scientific process is being followed properly. Concerning the educational community, teachers have to control the learning process, facilitate the discussion and established scientific practices to show a proper perspective of the scientific research (Mueller, M.P 2012, Shah, H. R. 2016). It is necessary a collaboration between scientists and teachers or facilitators in order to define the contents of the curriculum that projects tackle, to planify if changes in the educational program are needed (Shah, 2016; Castagneyrol, 2016) or accommodate the project tasks to students' diversity (Jenkins, L. L. 2011).

Students act as volunteers in citizen science projects and participate in projects in different activities of the scientific process at any step on which scientific knowledge, skills and methods can be learned. Different models of participation are designed by projects and followed by schools to introduce citizen science in formal education (Phillips T. B. et al. 2014, Paige, K. et al. 2015) although Bonney R. et al. (2009) defined it for the first time. Students have to follow specific protocols to develop the tasks assigned (Bonney, R. et al. 2009) on participating in the project. When participating in a citizen science project, students can classify data (ex. AI4MARS[16]), identify data (ex. Penguin watch[17]), build material needed to research (e.g., Desafío Bajozero[18]) or collect data (ex. Months of Canada[19]) among other tasks (Wiggins, A. et al. 2012).

Educational materials (posters, guides, videos, etc.) are created by projects to conduct experiments, support literacy, understand how investigation will be developed, know the timings, promote open discussions and advance in scientific knowledge. Also, training and conducting workshops are some of the tasks developed by scientists to train students (Cohn, J. P. 2008, Bonney R. et al. 2009). Those instruments and methods should be reflected in the curriculum (Mueller, M.P 2012, Schäfer et al. 2016, Shah, H, 2016).

### 5.4.3 Informal education

*Julia Lorke*

Due to the high number of citizen science projects around environmental, natural or physical sciences compared to citizen science projects within the context of humanities or social sciences, the section will mainly focus on the informal science education (ISE) sector. Starting with a clarification of what we mean by informal education and who the stakeholders are in the community of practice in ISE, we will build on the work by Kloetzer et al. (2020) to illustrate the connection between ISE and citizen science with examples from citizen science projects or other relevant developments in the interface of citizen science and informal education.

The Open education sociology dictionary defines informal education (2013) as "Unplanned and spontaneous learning of behaviours, norms, and values, which typically occurs outside of formal (school) settings." This type of learning is highly relevant as, according to Falk & Dierking (2010), on average people only spent 5% of their lifetime in formal education. While informal learning can happen anywhere anytime, informal education can happen in intentionally designed learning environments. The National Research Council (2009) description of informal science education acknowledges that informal education, in addition to everyday-life situations, can very well occur in spaces and programmes designed purposefully to enable the desired engagement and learning outcomes, as well as through science media. No matter if the learners engage with the learning opportunities intentionally or unintentionally in regards to learning. They define the following six strands to describe what learners may experience in informal learning settings:

- *"Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.*

[16] Zooniverse AI4MARS project (2020, October 15). Retrieved from https://www.zooniverse.org/projects/hiro-ono/ai4mars

[17] Zooniverse Penguin watch project (2020, October 15). Retrieved from https://www.zooniverse.org/projects/penguintom79/penguin-watch/classify

[18] Desafio Bajozero project (2020, October 15). Retrieved from https://ciencia-ciudadana.es/proyecto-cc/desafio-bajo-zero/

[19] Moths of Canada (2020, October 15). Retrieved from https://www.inaturalist.org/projects/moths-of-canada

- *Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.*
- *Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.*
- *Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.*
- *Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.*
- *Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science."* (National Research Council, 2009, p.4)

Many aspects mentioned in these strands align with those found in frameworks for individual learning outcomes in citizen science (e.g., Shirk et al., 2012, Phillips et al., 2018). However, it is the term "sometimes contributes to science" that sticks out and especially highlights the potential of citizen science to contribute to informal science education in a way that other formats cannot offer. According to Hecker et al. (2018, p.2), contributing to science is the "common, shared goal" of citizen science activities and thereby "distinguishes citizen science from areas such as experiential learning or environmental education".

Similarly, to informal science learning environments, we find that most citizen science activities are also "institutionally framed" or "located in organised, designed environments" (Dawson, 2014, p. 211) including various of the 17 stakeholders that were identified as part of the informal science education landscape or community of practice by Falk et al. (2012), e.g.: science centres; botanical gardens; natural history museums; zoos and aquariums; libraries; media; after-school science; youth-serving community organisations; adult community organisations; environmental organisations and science societies.

***Science Centres, Botanical Gardens, Natural History Museums, Zoos and Aquariums***

Many institutions in this section have an educational mission, in addition to a research mission, such as many museums and science societies; others are mainly focused on an educational mission aiming to open up opportunities for the public to engage with science and research like science centres, for example. citizen science offers a way to engage audiences in research as well as providing learning opportunities in an authentic context. This is a promising approach to address the dual mission of these institutions and provide opportunities to actively participate in authentic scientific research. Hence, it is not surprising that these institutions engage in citizen science in various ways. For example, institutions showcasing citizen science as an approach or citizen science projects at events or in exhibitions (e.g. Ecsite's Sparks exhibition,[20,] Berlin citizen science Day[21] at the Museum für Naturkunde), initiate and run citizen science activities themselves (e.g. Kew Gardens' The Lost and Found Fungi Project[22]

[20] Ecsite (2020, December 10). https://www.ecsite.eu/activities-and-services/news-and-publications/beyond-lab-beyond-sparks

[21] Museum für Naturkunde (2020, December 10). https://www.museumfuernaturkunde.berlin/en/press/press-releases/first-berlin-citizen-science-day

[22] Royal Botanic Gardens, Kew (2020, December 10). https://www.kew.org/science/engage/get-involved/citizen-science/lost-and-found-fungi

or the Royal Horticultural Society's Cellar Slug Hunt[23]) or contribute to capacity building efforts (e.g. the Chicago Botanic Garden's Citizen Science Academy[24]or the Guide to Citizen Science[25] from the Natural History Museum, London).

The collaboration of professional experts, amateur experts and interested hobbyists has a long tradition, especially in the case of natural history museums and science societies (Star and Griesemer 1989; Sforzi et al. 2018) with new technologies enabling new formats of such collaborations and providing opportunities to broaden the range of participants. In this sense, online citizen science projects can be an interesting way for organisations such as museums or botanical gardens to broaden their reach because participants would not be required to physically visit an institution. According to Trouille et al. (2017), crowdsourcing citizen science projects are used by museums "to engage their visitors, create metadata for digitized materials in their collections, and assist in their research efforts". As most museums and other institutions with collections are in the process of digitising their objects, citizen scientists are often asked to help with transcriptions of specimen labels, handwritten records, and other archive materials (e.g., AnnoTate[26], Notes from Nature[27], Die Herbonauten[28]). However, biodiversity monitoring projects in which citizen scientists are asked to record their observations of all or certain species in nature are quite common (e.g., Superproject[29], Big Seaweed Search[30] or FrogWatch). Ballard et. al. (2017) studied 44 natural history museum-led citizen science programmes and demonstrated that 26 of them, including some BioBlitzes, contributed to conservation outcomes, namely "conservation research, management, education and policy" (p. 87).

### *Libraries*

The role of public libraries for their local communities has changed and moved beyond places that provide books and internet access. Many offer a range of community outreach activities ranging from arts and crafts workshops to public debates, ICT courses, wellbeing activities, support groups, providing venues for community events (Scott, 2011) or offering a library of things. In addition to their long tradition in providing access to knowledge and learning opportunities, they aim for equity in access to their services and take community needs into account in their programming (Scott, 2011). Bonhoure, Cigarini, Perelló and Vicens (2019) advocated for public libraries to be redefined "as spaces where people, groups and communities can practise citizen science of value at the individual, community and local level". An

[23] Royal Horticultural Society (2020, December 10). https://www.rhs.org.uk/slugssurvey

[24] Chicago Botanic Garden (2020, December 10). https://www.chicagobotanic.org/education/citizen_science_academy

[25] Natural History Museum (2020, December 10). https://www.nhm.ac.uk/content/dam/nhmwww/take-part/Citizenscience/citizen-science-guide.pdf

[26] Zooniverse (2020, December 10). https://daily.zooniverse.org/2015/09/01/new-project-annotate/

[27] Zooniverse (2020, December 10). https://www.zooniverse.org/organizations/md68135/notes-from-nature

[28] Die Herbonauten (2020, December 10). https://herbonauten.de/

[29] Natural History Museum of LA County (2020, December 10). https://nhm.org/community-science-nhm/superproject

[30] Natural History Museum (2020, December 10). http://www.bigseaweedsearch.org/

example of a citizen science project led by public libraries is "Jocs per l'Habitatge (Games for Housing)"[31] in which through a co-created process new data on access to housing was generated and applied to develop recommendations for new housing strategies. A helpful resource to embed citizen science is *The Librarian's Guide to Citizen Science* (Cavalier, Nickerson, Salthouse & Stanton, 2019) which provides an introduction to citizen science but also practical recommendations and tools such as a checklist for programming.

Another push to make use of the synergies between libraries and citizen science is led by The European Association of Research Libraries (LIBER) which sees libraries as a key player in realising the EU's Open Science agenda (Ignat et al., 2018). Within that effort, supporting citizen science plays an important role (Ayris et.al, 2018). In their Roadmap LIBER outlines four key recommendations to establish the libraries' stakeholder position: 1) Promoting the role of the library in citizen science and supporting citizen scientists in their work, 2) using the institutions' credibility and expertise to ensure ethical conduct and scholarly practice, 3) developing guidelines for methodologies and policies and 4) capacity-building in scientific communication, information technologies and project management for citizen science (Ayris et al., 2018). Spearheading the field of citizen science and research libraries within LIBER are the University of Barcelona (e.g., providing advice on intellectual property, data management and open access[32]), University College London (e.g., Transcribe Bentham[33]), the University of Southern Denmark (e.g., A Healthier Funen; Overgaard & Kaarsted, 2018) and Qatar National Library (e.g., Citizen Science Workshop 2019[34]) (Ignat et al., 2018).

### *Media*

Traditionally informing and educating their audiences are aims of media outlets (see BBC mission[35]), so they may cover the launch, existence or results of citizen science projects (e.g., BBC Digital Planet's report on Dreamlab[36]), they may tell stories about individual citizen scientists (e.g., "iNaturalist Does More Than ID Plants" in Sierra magazine[37]) or report on the general approach, its relevance and impact (e.g., Nature's "No PhDs needed: how citizen science is transforming research"[38]). Media coverage increases the visibility of citizen science (see 4.6) and by raising awareness of the concept or individual projects and resources, media coverage can help projects with volunteer recruitment (Robson et al., 2013). Thus, it's not surprising that there are several examples of collaborations including media partners. For example, between 2005 and 2006 Woodland Trust and the BBC collaborated on the

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[31] Open Systems (2020, December 10). http://www.ub.edu/opensystems/projectes/ciencia-ciutadana-en-accio/

[32] CRAI Universitat de Barcelona (2020, December 10). https://crai.ub.edu/en/crai-services/intellectual-property

[33] University College London (2020, December 10). https://blogs.ucl.ac.uk/transcribe-bentham/about/

[34] Qatar National Library (2020, December 10). https://events.qnl.qa/event/nXMM1/EN

[35] BBC (2020, December 10).https://www.bbc.com/aboutthebbc/governance/mission

[36] BBC(2020, December 10). https://www.bbc.co.uk/programmes/w3cswhd8

[37] Sierra (2020, December 10). https://www.sierraclub.org/sierra/inaturalist-does-more-id-plants

[38] Nature (2020, December 10). https://www.nature.com/articles/d41586-018-07106-5

Springwatch survey[39] that ran along with the popular BBC Springwatch TV programme, asking citizens to submit observations on, for example, ladybirds, bumblebees and frogspawn. The partnership between Zooniverse's SpaceWarps and BBC Stargazing Live even won an award for their collaboration.[40] The BBC apparently found these collaborations fruitful as they later engaged in the development of the citizen inquiry platform nQuire[41] in collaboration with the Open University and have since been involved in several additional projects (e.g., Gardenwatch[42]). Examples for media partnerships in citizen science can also be found in other countries, for example, Germany (e.g., Apfelblütenaktion[43], a collaboration between SWR (a German radio and TV station) and Heidelberg University of Education) and Denmark (e.g., A Healthier Funen; Overgaard & Kaarsted, 2018).

### *After-School Science*

The after-school landscape seems to vary from country to country. In the US, after-school programmes across many different subject areas are very common. Hence, we also find several examples for programmes that are citizen science or include participation in a citizen science project among other activities. The Dragonfly Detectives[44], a project led by the North Carolina Museum of Natural Sciences, engages children in grades 4–8 in citizen science (Goforth, 2018). The Science Action Club[45] programme developed by the California Academy of Sciences embeds citizen science activities (e.g., BugSafari) within their educational curriculum. They report to have engaged 62,000 youth and educators in over 400 locations since the programme started in 2011. Another example is the Mad Science project which focused on engaging students from low-income communities in, for example, participatory sensing and applied an apprenticeship model to enable interactions between students and scientists. Heggen et al. (2012) reported more favourable views of technology, enjoyment of interactions with technology, and increased aspirations for STEM career paths as outcomes for participation in the Mad Science programme. In addition to after-school programmes, citizen science activities can be part of youth summer programmes. Ballard et al. (2017b) studied how youth can develop knowledge, skills, roles and agency in such programmes and developed resources for practitioners showcasing case studies[46] and key practices[47].

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[39] BBC (2020, December 10). http://www.bbc.co.uk/pressoffice/pressreleases/stories/2005/05_may/30/springwatch.shtml

[40] Zooniverse (2020, December 10). https://daily.zooniverse.org/2014/06/26/another-award-for-the-zooniverse/

[41] IET (2020, December 10). https://iet.open.ac.uk/projects/tomorrows-world-nquire

[42] BBC (2020, December 10). https://www.bbc.co.uk/programmes/articles/4gjThGt61ndDfXqcWL04rqn/gardenwatch-now-closed-to-submissions

[43] SWR (2020, December 10). https://www.swr.de/wissen/apfelbluete/

[44] https://dragonflydetectives.wordpress.com/

[45] https://www.calacademy.org/science-action-club-sac

[46] https://education.ucdavis.edu/yccs-case-studies

[47] https://education.ucdavis.edu/yccs-key-practices

***Youth-Serving Community Organisations, Adult Community Organisations, Environmental Organisations & Science Societies***

Youth serving organisations have discovered citizen science as one way to engage youth in STEM and as an activity that can support the development of various skills from scientific thinking to using an app to public speaking. Information and resources on citizen science are provided by or for many youth-serving organisations, e.g., various extensions of 4-H youth development programmes[48], STEM4Youth[49] or The Y[50]. Girl Scouts USA teamed up with the citizen science platform SciStarter to embed citizen science in the Scouts activities.[51] Educational materials are provided for troop leaders in the form of a toolkit. The platform has created a special access for troop leaders and their scouts, so they can monitor and support the girls on their "Think like a scientist" journeys over several years. The scouts get credit for their participation in the citizen science activities and can earn citizen science badges for various different stages.

There are various examples of more adult-focused organisations, such as science societies or environmental organisations, engaging in a broad variety of citizen science activities. One of the longest running citizen science surveys, for example, is the Audubon Christmas Bird Count[52] run by the National Audubon Society. Some embed citizen science as part of their wider agenda. The Marine Conservation Society, for example, runs Seasearch and is a partner in the Big Seaweed Search, but lists those citizen science activities on their website[53] in the section "Get active" which also includes environmental education or stewardship activities, such as beach cleans. The National Geographic Society provides a collection of resources on citizen science for educators and citizen scientists[54], ran stories about citizen science projects, offered grants for projects and since 2017 co-funds iNaturalist[55], one of the most popular biodiversity recording apps. Public Lab is an example for a community organisation leveraging open technology to run collaborative participatory science projects. The topics range from air quality and disaster response to waste and their approach is focused on equity and social justice.

Although this subchapter can only provide a brief overview on the various forms in which informal education stakeholders engage in citizen science and citizen science activities become part of the informal education landscape, the descriptions hopefully highlight the potential synergies between the fields.

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48 https://nys4-h.org/projects/#citsci

49 http://www.stem4youth.eu/citizen-science/

50 https://www.ymca.net/summer-buzz/ways-for-kids-and-teens-to-become-citizen-scientists

51 https://scistarter.com/girl-scouts-faq

52 Audubon (2020, December 10). https://www.audubon.org/conservation/science/christmas-bird-count

53 Marine Conservation Society (2020, December 10). https://www.mcsuk.org/get-active/

54 National Geographic (2020, December 10). https://www.nationalgeographic.org/topics/citizen-science/

55 iNaturalist (2020, December 10). https://www.inaturalist.org/pages/about

### 5.4.4 Online perspectives in citizen science

*Patricia Santos, Miriam Calvera-Isabal*

Online education promotes development on computer and technology skills, educational engagement in specific tasks related to computer technology, autonomy on learning and brings them closer to societal realities (by using simulators or online resources) (Robinson et al., 2008). With the emergence of the internet, web-based applications have been developed to support synchronous and asynchronous learning, giving the opportunity to the students to learn when and where they want and providing teachers a variety of learning resources to use in schools (Aristeidou et al., 2020). Additionally, during the last years and especially the last course because of the COVID-19 pandemic, the need to provide online support for education has become a priority, which has led to an advance in technological learning and development of many online applications (Dhawan, S. 2020).

Online citizen projects provide students the opportunity to be engaged in different types of projects for different topics and forms of participation (Curtis, 2015; Doyle et al., 2018). Nevertheless, Doyle et al. (2019) conclude that teachers prefer to address issues of local interest. In general, blended learning is supported by projects because protocols or communication are followed by students and teachers online from the project web page itself (ex. Vigilantes del aire[56] or Meet mee voor een schonere lucht[57]) although some platforms are completely dedicated to online citizen science (ex. nQuire[58] or Zooniverse[59]) (Herodotou, C. et al. 2014, Herodotou, C. et al. 2018). In general, most of the platforms have specific documentation about how to participate in a project from the school context.

There are different ways to participate in online citizen science (OCS) projects in the classroom but depends on the learning outcomes identified by teachers to fulfil (learning about research process, specific topic, etc.) and the project needs. Students have to understand what is required and follow the protocol to participate in the project. Pre-requirements to participate in OCS are: to have an internet connection and a computer/smartphone/tablet as a minimum (Doyle et al., 2019).

For those projects that follow a blended learning method, teachers participate in workshops to learn more about the project and how to conduct it, helping them to implement their teaching units (National Academies of Sciences, Engineering, and Medicine 2018, Doyle, C. et al. 2019). In general, there are many materials that explain all the educational aspects and the communication between teachers and scientists

[56] Vigilantes del aire project (2020, October 15). Retrieved from https://vigilantesdelaire.ibercivis.es/

[57] Meet mee voor een schonere lucht project (2020, October 15). Retrieved from https://www.luchtpijp.be/aan-de-slag

[58] nQuire platform (2020, October 15). Retrieved from https://nquire.org.uk/discover

[59] Zooniverse platform (2020, October 15). Retrieved from https://www.zooniverse.org/

is usually fluid (ex. OdourCollect[60], SCENT project[61], Vigilantes del aire[62]). For those projects that are completely online, and especially those that use a platform as a participation tool, there is information about the project (frequency, development time, ideal age of group, etc. (ex. Space Fluff project[63])) and pages with educational information in addition to forums where participants (teachers and students) can post comments or doubts and both other volunteers and coordinators will answer their questions (ex. Zooniverse[64] have for many projects a page with educational information and for each project their specific forum -called talk). These forums promote participation, engagement and motivation, critical thinking, learning with and by others and create a community that supports the learning process (Carlsen et al., 2014; Luczak-Roesch et al., 2014; Doyle, 2018).

It is important to pay special attention to those citizen science platforms (ex. EU-citizen science platform[65], Observatorio de la ciencia ciudadana español[66], Australian citizen science[67] or SciStarter[68]) or other associations that dedicate some efforts to create working groups or specific actions to involve students in citizen science (ex. Österreich forscht[69], Zentrum für Citizen science [70], Vigie Nature école[71], Environmental protection

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[60] Educational resources for OdourCollect project (2020, October 15). Retrieved from https://ciencia-ciudadana.es/disponible-la-unidad-didactica-ciencia-ciudadana-para-monitorizar-la-contaminacion-odorifera/

[61] SCENT project educational resources (2020, October 15). Retrieved from https://scent-project.eu/teachers-guide

[62] Vigilantes del aire educational resources (2020, October 15). Retrieved from https://ibercivis.es/wp-content/uploads/2020/01/VIGILANTES_DEL_AIRE_UNIDAD_DIDA%CC%81CTICA.pdf

[63] Space Fluff project in SciStarter platform (2020, October 15). Retrieved from https://scistarter.org/space-fluff

[64] Zooniverse platform (2020, October 15). Retrieved from https://www.zooniverse.org/

[65] EU citizen science platform (2020, October 15). Retrieved from https://eu-citizen.science/

[66] Observatorio de la ciencia ciudadana español (2020, October 15). Retrieved from https://ciencia-ciudadana.es/

[67] Australian citizen science platform (2020, October 15). Retrieved from https://citizenscience.org.au/

[68] SciStarter platform (2020, October 15). Retrieved from https://scistarter.org/finder

[69] Österreich forscht platform working group (2020, October 15). Retrieved from https://www.citizen-science.at/netzwerk/arbeitsgruppen/ag-schule

[70] Zentrum für Citizen science (2020, October 15). Retrieved from https://zentrumfuercitizenscience.at/de/citizen-science-schule/

[71] Vigie Nature école educational resources (2020, October 15). Retrieved from https://www.vigienature-ecole.fr/escargots

agency (EPA)[72], SDU[73], Luonto-Liiton Kevätseuranta[74] or iNaturalist[75]).

Learning is one of the main purposes of participating in OCS projects. Kloetzer et al. (2013) demonstrate that participation on virtual citizen science projects promotes almost six different learning outcomes (Figure 2) related to different activities done. But, in order to ensure successful learning (Masters, 2016), students should have personal assistance if they have technical problems or doubts about the project or the resources they have available (Chen et al., 2010).

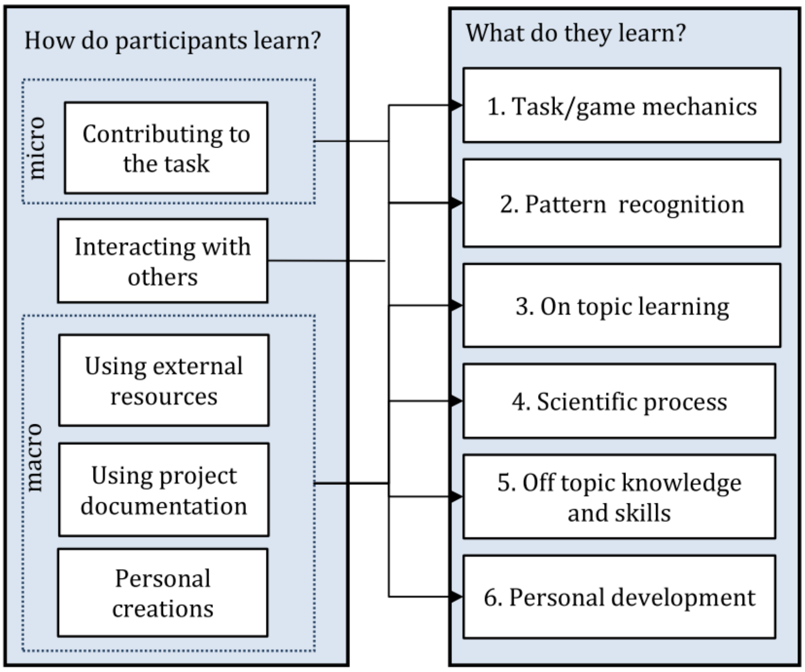


**Figure 2**. Learning in citizen science projects (Kloetzer et al. 2013).

### 5.4.5 Examples of educational citizen science projects

There are many strategies to classify educational citizen science initiatives (by learning outcomes, by project type, by how students participate, etc.) but it has already mentioned through the previous sections many projects related to all these categories. Below it is presented a list of selected projects that illustrates almost all the classification typologies.

**Every name counts**[76]: Project *developed online* through citizen science Zooniverse

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[72] Environmental protection agency educational resources (2020, October 15). Retrieved from http://www.epa.ie/researchandeducation/

[73] Citizen Science & Active Schools (CSAS) from SDU association (2020, October 15). Retrieved from https://www.sdu.dk/en/forskning/forskningsformidling/citizenscience/activeschools

[74] Luonto-Liiton Kevätseuranta association educational resources (2020, October 15). Retrieved from http://kevatseuranta.fi/opetukseen/

[75] iNaturalist teacher's guide: https://www.inaturalist.org/pages/teacher's+guide

[76] Every name counts (2020, October 15). Retrieved from https://www.zooniverse.org/projects/cseidenstuecker/every-name-counts/about/education

platforms. It's a project about history whose goal is to "*ensure that all the names in the millions of documents stored in the Arolsen Archives can be found in the online archive – so that people all over the world can easily access information on the fate of their relatives*". There are additional resources available to ensure educational outcomes.

**The Influence of Social Media on Vaccination Hesitancy in the European Union**[77]: Project developed online through SciStarter citizen science platforms. It's a project about Health & Medicine that has to be developed only once. Its goal is "*Identifying connection between social media and vaccine hesitancy in the EU*". Specially dedicated to High school (14 - 17 years), College, Graduate students, etc.

**Bug Safari**[78]: Project promoted by CalAcademy's Science Action Club developed locally and integrated in iNaturalist platform. Is a project about local Biodiversity which "On local field expeditions, middle school youth search for bugs, collect specimens, and post photos to SAC's iNaturalist project".

**Op zoek naar fruit en groenten**[79]: Project developed locally with a camera and email account. It's about "plants, grain, fruits or vegetables in paintings". Volunteers take photos from paintings in a museum and "help biologists understand the evolution of the plant kingdom".

**CoKoNet**[80]: Project developed online. Is a project about sociology. The project evaluates "the consequences that the reduction of social contacts during the Corona crisis has on our personal behavior and on our communal contact network". All the data will be presented in a workshop for schools.

**Discover earth**[81]: Project developed locally. "Supports teachers and schools in understanding how they can achieve a more sustainable planet, with a focus on citizen science, climate change and the environment". Provides activities, workshops and resources.

**Cities at night**[82]: Project developed locally. "The main goal of the project is to tag, locate and georeference the archive of night time images of the Astronauts of the International Space Station". For schools, it is a powerful "too to teach geography, increase awareness about the light pollution problem".

**Sounding Soil**[83]: Is an Earth science project developed locally and online. The project's

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[77] The Influence of Social Media on Vaccination Hesitancy in the European Union (2020, October 15). Retrieved from https://scistarter.org/the-influence-of-social-media-on-vaccination-hesit

[78]Bug Sfar (2020, October 15). Retrieved from: https://www.inaturalist.org/projects/bug-safari

[79]Op zoek naar fruit en groenten project (2020, October 15). Retrieved from https://www.iedereenwetenschapper.be/projects/op-zoek-naar-fruit-en-groenten

[80] CoKoNet project (2020, October 15). Retrieved from https://cokonet.pages.ist.ac.at/ in Young science zentrum webpage (https://youngscience.at/de/angebote/projekte-zum-mitforschen/mitforschen-von-daheim/)

[81] Discover earth project (2020, October 15). Retrieved from https://earthwatch.org.uk/get-involved/education-and-schools/discover-earth

[82] Cities at night project (2020, October 15). Retrieved from https://citiesatnight.org/ in EU-citizen science platform (https://eu-citizen.science/project/45)

[83] Sound soil project (2020, October 15). Retrieved from https://www.soundingsoil.ch/ in Schweiz forscht platform (https://www.soundingsoil.ch/)

aim is "try to acoustically measure the biodiversity in the soil with sound recordings and to examine the relationships in the environment".

**Water - Broad general education**[84]: Is a project developed locally in Scotland about water and beaches. The main objective is to "find out about Scotland's bathing waters and beaches near" volunteers.

**EnviroCitizen: Ciencia Ciudadana Para Una Ciudadanía Ambiental**[85]: The participation is locally through Europe. Is a project that "aims to research how to encourage environmental citizenship through engagement with citizen science".

**The Novels Survey: Coming of Age**[86]: It is a project about literature and is online. The volunteers have to Rate BBC selection of novels about Coming of Age.

### 5.4.6 Possibilities and obstacles of citizen science in Education

As it was mentioned in previous chapters, citizen science promotes scientific skills, knowledge, learning in science, technological skills, engaging in science and changes in behaviour and attitude toward science (Ruiz-Mallén, 2016). But, how could these aspects be measured? Assessing the learning outcomes is not an easy task because scientists in general don't define these aspects as part of their project goals. "These learning outcomes should be specific, measurable, attainable, relevant, and timely" (Jordan, 2012). Phillips et al. (2018) identified different learning outcomes from different projects being some of them: "Interest in science and environment", "skills of science inquiry" or "Knowledge of the Nature of science" etc.

Phillips et al. (2015) defines evaluation as a "comprehensive process that involves a strategy to plan, implement, and report results" and needed to obtain evidence about learning outcomes and know strengths and weaknesses of the project. It can be done during the project life cycle but the final conclusion should be obtained at the end. The User's Guide for Evaluating Learning Outcomes from citizen science of The Cornell lab of Ornithology (Philips et al., 2015) defines three types of evaluation: front-end, summative or formative. There should be defined some indicators that "need to be targeted, feasible, valid, and reliable" for each learning outcome identified. (Jordan et al., 2012; Phillips et al., 2014).

There are many evidences of how citizen science can contribute to STEM career motivation (Hiller, S. E. et al. 2014), promote ecology (Kobori et al., 2016), knowledge about biodiversity, biology or water evaluation (Eberbach et al., 2009; Oberhauser et al., 2012; Thornton et al., 2012; Vitone et al., 2016; Ballard et al., 2017; Kelemen-Finan et al., 2018) and critical thinking and/or in community (Fazio et al., 2015; Masterson et al., 2019). These contributions have to be aligned with learning outcomes defined by projects and identified by teachers in the curriculum.

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[84] Water - Broad general education project (2020, October 15). Retrieved from https://www.environment.gov.scot/educational-resources/get-learning-water/water-broad-general-education-early-to-fourth-level/

[85] EnviroCitizen: Ciencia Ciudadana Para Una Ciudadanía Ambiental project (2020, October 15). Retrieved from https://www.envirocitizen.eu/

[86] The novels survey: Coming of Age from nQuire platform (2020, October 15). Retrieved from https://nquire.org.uk/mission/the-novels-survey-coming-of-age/contribute

The use of information and communication technologies (ICT) have increased during the last years, facilitating the implementation of citizen science projects, not only because of the presence of projects on internet (platforms, web pages, etc.) but also to the use of technology (mobile, cameras, virtual realities, sensors, etc.) to develop project activities by students (Herodotou et al., 2014). The use of ITCs is proven to increase student's motivation, interest in science, technology and STEM careers and increase in knowledge of the field of science or learning (Tsivitanidou et al., 2020).

Finally, gamification has been introduced as a method to conduct a citizen science project (e.g., SCENT explore game[87]). Volunteers have to solve different real-life problems or activities -synchronous or asynchronous- related to the scientific project to pass the game (Crowston et al., 2013; Iacovides et al., 2013; Curtis 2015; Rallapalli et al., 2015; Tinati et al., 2015; Tinati et al., 2016; Tinati et al., 2017; Tsivitanidou et al., 2020).

## 5.5 Visibility of citizen science

*Sven Manske, Julia Lorke*

Common ways for citizen science projects and activities to become visible to their stakeholders, potential volunteers and the public include traditional media, projects websites, national or international citizen science platforms as well as social media outlets. Media partnerships can be project-specific (e.g. Apfelblütenaktion[88], a collaboration between SWR and Heidelberg University of Education) or platform-based (e.g. nQuire[89], a collaboration between the Open University and the BBC). Although platforms seem to be considered as less relevant to projects coming from the citizen social science field (Göbel, Henke & 2019), many projects have their own web presence and/or are listed on citizen science platforms that often operate on a national or even international level (e.g. Bürger schaffen Wissen[90], EU-Citizen.Science[91]). At this point it should be noted that since citizen science activities could potentially be conducted entirely without any form of media coverage or online representation, there is a possibility that some of them are not detectable with the web-focused methods.

New and emerging technologies are heavily influencing and transforming scientific research projects during the last decades (Newman et al., 2012) and are opening up

[87] Mobile SCENT explore app (2020, October 15). Retrieved from https://play.google.com/store/apps/details?id=com.xteamsoftware.scentexplore&hl=en_US

[88] SWR Wissen, Apfelblüte (2020, October 15). Retrieved from https://www.swr.de/wissen/apfelbluete/

[89] IET, nQuire project (2020, October 15). Retrieved from https://iet.open.ac.uk/projects/tomorrows-world-nquire

[90] Bürger schaffen Wissen (2020, October 15). Retrieved from: https://www.buergerschaffenwissen.de/en

[91] Museum für Naturkunde Berlin, EU-Citizen.Science (2020, October 15). Retrieved from https://eu-citizen.science/

new ways of making results, processes, people and networks visible and partly open to the public. Besides traditional media outlets and established web resources, the use of mobile technologies has become more important in the field of citizen science. Mobile technologies are not only enabling new ways to collect data remotely and on a large scale through crowdsourcing, but also support the dissemination and communication of research results. Beyond this, social media sites and channels let novices and non-experts participate in scientific activities and involve them in scientific discourse to some extent. While the basic technology for enabling citizen science activities is a straightforward crowdsourcing infrastructure (for example, a data collection app), there is an inherent need to activate and acquire volunteers for such activities and ideally maintain their engagement over an extended period of time. Robson, Hears, Kau and Pierce (2013) have shown that social media sites such as Facebook or Twitter can be used to recruit and promote such crowdsourced citizen science activities, with the effect of a social media campaign (measured by the download rate for the project's app after each communication effort) being similar to the effect of an international press release and the corresponding media coverage.

For some citizen science projects, the use of social media is quite crucial as they do not form explicit or formal project structures. Daume and Galaz (2016) investigated the so-called implicit or embryonic citizen science communities that used Twitter as a communication backbone. The projects investigated are not formalized or institutionalized as they are not created or funded by specific initiatives. This unveils contexts, in which citizen science activities are formed in a bottom-up approach. Those informally organized projects are of particular interest for CS Track as they can extend the corpus of projects represented by the Work Package 2 database that was mainly sourced from established citizen science platforms. Identifying and analysing those types of citizen science activities will provide insights into trending citizen science topics and developing citizen science communities beyond the already captured more formalised landscape of citizen science.

While the work by Daume and Galaz (2016) has shown that individuals might use social media to network and connect to other "citizens" to kickstart or initialise citizen science activities, other formalized or institutionalized citizen science activities may choose to communicate within a closed ecosystem for project-internal aspects, but applying a different focus when communicating to the outside. Though when this different focus shifts to promoting the institutions rather than promoting the science activity, this communication strategy might be counterproductive. This "missed opportunity" of using communication channels to showcase the scientific process and the people involved have been explored by Brown Jarreau, Dahmen and Jones (2019) who found that although museums use Instagram as a promotional channel, this practice does not put the science or the scientists behind the scenes in focus. In the sense of citizen science, this would allow mediating the interaction between scientists and citizens. Tancoigne (2019) explored this process of mediation between citizens and scientists on Twitter and found out that there is a third role of actors, the "citizen science brokers". As a sidenote, Tancoigne explains that most of the actors, who call themselves "citizen scientists", are professional scientists from other research fields. This has implications for the work in CS Track, because this uncovers the challenge of identifying "real" citizen scientists that participate in such projects as non-professionals ("lay participants"), making it difficult to establish a "dialogue" between those actors.

Research has shown the importance of direct communication between volunteers and scientists in such programmes. According to Masters et al. (2016), citizen science initiatives with well-functioning communication channels such as forums or blogs are better functioning regarding economic measures and active participation, which is connected to knowledge co-creation in the discourse and exchange with scientists. With the premise that participants extend their (scientific) knowledge and believe to learn about science, such communication structures tend to support motivational factors. A similar experience has been documented by Liberatore et al. (2018), where a Facebook group has been used to support a citizen science project in the context of bird watching. They highlight the important role of such platforms in establishing and providing access to public and private community spaces, where the latter is established through administrators or moderators. Apart from the organisation and infrastructure of communication, other factors coinciding with visibility have been explored in research. Bautista-Puig, De Filippo, Mauleón, and Sanz-Casado (2019) defined altmetric and bibliometric indicators to assess social interest in science. It turned out that open access publications tend to improve the visibility of projects through social media, with the highest volume on Twitter compared to other social media sites. Other indicators that have been explored in this research work are number of DOIs or the distribution of publications across the web of science categories, which are particularly of interest for the CS Track project (e.g. section 9.3).

Social media platforms seem to provide a solid foundation for citizen science projects – not only for the pure collection of crowdsourced data but also for knowledge co-creation, knowledge exchange and the building of expertise among non-experts in creating data of high quality that are valuable for science. Further, it enables social interaction between the stakeholders of citizen science projects, namely citizen scientists, project owners, practitioners, and the public through such open dissemination channels (Mazumdar & Thakker, 2020). Particularly the latter, communicating actively to a magnitude of people, e.g., through mass media, does not only help to massively increase the exposure of science activities, but this involvement of the public also increases the credibility of scientists and projects, as well as the participation of citizens in science (van Vliet, Bron & Mulder, 2014).

## 5.6 Economic considerations in Citizen Science

*Raul Drachman*

The purpose of this section is to understand – identify, define, qualify – the role of economic considerations in CS. As in other sections, we intend to reflect here on the way "our" theme –economic considerations – correlates *differentially* with CS Track's characteristics and reach. The questions that will be posed here will not only address the essence of that theme in the context of citizen science projects but especially its link to our project, putting any question in its unique perspective, considering its components, means, approaches, objectives, target users of its results, etc. Thus, if we talk about the productivity of voluntary work, for example, as an "economic aspect", we are not going to refer to it in depth as a topic of economic interest but mainly to ask when and how it shows and is relevant for citizen science and citizen science projects and, most importantly, how it could manifest in the framework of the comprehensive picture of citizen science that our project is intended to produce and expose. This makes, in our view, a valid approach to refer to "economic considerations" as a distinct sub-section of D1.1/4.

Although it is apparent that citizen science is, first and foremost, a scientific-social-organisational phenomenon, it is the underlying set of economic considerations that will factually enable or not the endeavour and determine many of the conditions for its sustainability. Given the basic scientific motivation and economic determinants, however, the latter, in the citizen science context, do not necessarily have to be taken in the rigid, profit-driven manner a commercial enterprise (for example) would approach them, based on pure cost and benefit assessment. Indeed, we are talking about different endeavours. Development X is not the same development X if it is done in the lab and facilities of a company or university as if it is done in the time, expertise and geographical distribution conditions of a standard citizen science project. Usually these other elements – and especially considering also the socio-educational objectives that are proper of a citizen science project – very much relativise any insight one could make through the cold analysis of the disclosed economic-financial data of the citizen science project in case. As put by Sauermann and Franzoni (2015), a citizen science project is, after all, "a new organizational mode of conducting scientific research", with different opportunities and challenges, opening the ground, as well, for addressing other – and in many cases, broader – objectives that cannot always be conceivable in a standard profit-driven undertaking.

As a matter of rule, and with few exceptions, this special attention to the "other-than-economic factors" is a salient characteristic of citizen science projects and of the way they have been researched. More particularly, the science core of these projects has usually been seen as first among equal objectives, or characteristics, deserving and getting extra attention, above and beyond the economic considerations (within reasonable limits) and the "other" aspects (e.g., educational value). Further quoting Sauermann et al. (op. cit.), "Notwithstanding potential benefits for science education, our discussion will focus on the potential of crowd science [for citizen science] to advance the production of scientific knowledge". The economic side is not being disregarded, but it is put on a second level of attention. Quite surprisingly, even the *Ten Principles of Citizen Science* of the European Citizen Science Association seem to endorse this apparent downgrading of the economic considerations (see ECSA, 2015). All conceivable ethical, environmental, scientific, participatory, and other aspects of citizen science are considered in these Principles, but no economic aspects (cost, efficiency, comparative achievements, growth potential, etc.) are referred, even indirectly, in them. Principle #9 reinforces this view: "Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact." If this is done on an economically sensible basis, or not, is another question.

In essence, our project adopts the approach of keeping the science (and other "classical") content and objectives in the front, and we do not propose to change this here. Economic factors, however, are an important component of the set of concerns (certainly in pre-launch stages) of all citizen science projects, and the experience revealed in this regard from the analysis of past and running projects will be necessary for any learned decision of starting (or up-scaling – see below) a project. Based on existing knowledge, it is our purpose here to take a closer look at the economic aspects relevant to citizen science so that they could be pondered in a framework that considers additional, other aspects that may eventually be viewed as "more important".

### 5.6.1 Approach and focus

Each and every citizen science project has its own economic facets, with unique qualitative and quantitative attributes and magnitudes, characterising also (and being conditioned by) the financial, organisational, legal / regulatory, environmental, socio-cultural and the other frameworks that make its economic profile. Addressing all these aspects in a given project could be possible only through their detailed observation and analysis *there*, which would most probably reveal a different picture than in any other project. So this is not the kind of information that CS Track will seek or provide – at least not for a meaningful number of projects – as it is not possible to reliably generate such information (say, creating our own *Standard & Poors 500 (-like) Guide* for Citizen Science "businesses") in a project like ours. Instead, in what is relevant to this subsection our project will focus on determining categories of concepts, problems, research items, etc. with a visible economic dimension, and inform the interested user/reader about the extent of their presence, relevance and implications in citizen science projects and citizen science in general. Indeed, we deem it important, for our purposes here, to list **the aspects of economic interest that were raised in the literature** (or will/may be found out or hypothesized by us in our work in the project) as relevant for citizen science or citizen science projects rather than mentioning in which specific projects they were detected or measured and which were the concrete findings. Based on this "inventory" of elements or aspects, we – and ultimately the user of our results – will be able to tailor-make any desired search or inquiry of economic character to our/their needs, focusing on any desired citizen science project or group of projects. This way we intend to set the basis for an informed approach to look at the citizen science area and its activities with the aim of comprehending their economic side.

### 5.6.2 Aspects of interest in the economic realm in the citizen science area - Horizontal subjects

Estimations of "economic worth" of citizen science projects have been carried out via an evaluation of **the alternative cost of otherwise free (volunteer) work** used in those projects. Bonney et al., 2016, referred to and compiled findings built on the basis of this approach to assess economic worth contributed by two teams of researchers – Sauermann and Franzoni, 2015, and Theobald et al., 2015 – that worked on large sets of projects and data. The former authors focused on seven projects from the Zooniverse portal, using high-resolution involvement data of more than 100 thousand participants during 180 days in 2010. Under various assumptions, they estimated the total value of their "production" at about $1.55M, or about $222K per project on average (with a big variance, though, as the per-project data ranged from $22K to $654K). Theobald et al. 2015, surveyed 388 biodiversity-related projects, in which they estimated the annual numbers of volunteer participants (citizen scientists, in our usage here) between 1.36 million and 2.28 million, also here with a great variation on a per-project basis. The estimated value of the in-kind contribution ranged between $667 million to $2.5 billion annually.

Some of these numbers are quite impressive, although the width of the estimation intervals hints to the challenges embedded in the estimation processes and calls for their cautious use. Indeed, as mentioned in Wikipedia (https://en.wikipedia.org/wiki/Citizen_science, 21.11.20) quoting some authors (e.g., Frias et al., 2018), **data accuracy** is a concern in most empirical research on the citizen science subject. To be sure, large estimation variances show in virtually all variables of economic interest (numbers of participants and other measures of size of projects, extent of work investment and its categorisation, output and productivity indicators, etc.). Aceves-Bueno et al., 2017, surveyed a large number of projects (and research approaches, by several authors), focusing on the data accuracy issue in citizen science. The authors concede that "the cost-effectiveness of citizen science data offers the potential for scientists to tackle research questions with large spatial and/or temporal scales", citing, among others, Brossard et al. 2005, Holck 2007, Levrel et al. 2010, Szabo et al. 2010, Belt and Krausman 2012. But data accuracy does remain an obstacle to draw reliable insight of wide validity. In any case, it is important to note that cost-effectiveness in citizen science is often seen as *outweighing* data quality issues (if these are properly managed), at least at the research level (Gardiner et al., 2012).

Besides issues of data accuracy, research has questioned whether the plain comparison of labor costs (paid vs. unpaid) is the right way of assessing the relative economic contribution of the citizen science format (even if we still accept that it is in the use of free work where the bulk of the attention to economic considerations should be put). Indeed, this may be an oversimplified comparison, considering the fact that, to a project-dependent extent, volunteer labor often needs **training** (expectedly more so than scientists in a similar project). Clearly, this consideration affects the originally simple equation; see Fauver, 2016, and its bibliography. This author (among others) found that "the citizen science projects studied [in his thesis] are not notably cheaper than their professional counterparts but are lauded for their benefits of education, community engagement, and stewardship". Considerations of this kind put in a richer perspective the volunteer work as an economic factor and, more in general, the economic analysis of citizen science. As written before, assessing the cost-benefit balance in citizen science is a more complex task than in regular business settings. The presence of values and other non-purely-economical (or not easily quantifiable) factors in the "equation" do add reasons to be careful in the analysis (and usually prevent generalized conclusions in this regard).

The **natural geographical distribution** as a factor in the relative cost analysis has not always been paid all due attention *when focusing on the economics* of citizen science projects; it has, of course, in the context of evaluating citizen science projects as scientific and educational endeavours, and as part of the participation motivation.

The utilisation of **new technologies** is an additional factor behind the (a priori, at least) relatively lower costs of citizen science projects. In fact, sometimes not much more than personal tablets or laptops (together with the ready disposition of youngsters to master them in novel environments) are needed for their implementation, and indeed, citizen scientists using and even building or adapting their own instruments are commonplace. Modern technologies mean increased options for these projects and are a sine qua non for their additional characterising features (internal communication, discussion, dissemination and recognition of achievements, etc.), around which the motivational apparatus can be built (see, e.g., Drollette, 2012 and Fauver, 2016). Although the utilisation of others' (and in particular, volunteers') technological means is a potential cost-saving factor, it does not seem to have been duly attended (evaluated) in currently available research; these evaluations, when attempted on large sets of projects with the aim of identifying regularities, seem to have considered almost exclusively the alternative cost of *work*, not of equipment. In any case, there have been many studies addressing creative forms of equipment utilisation that are thinkable in a citizen science (open-source hardware, digital manufacturing, 3D printing, DIY, etc.; see Pearce, 2012 and 2016; Baden et al., 2015; Damase et al., 2015; Zhang et al. 2013).

Another subject with economic implications that has caught attention in citizen science research is the **up-scaling** of existing projects, intimately related to the concept of sustainability (which, in a citizen science context, refers to both project-internal conditions to permit a continuation and to external – often environmental – constraints). Maccani et al., 2020, analysed the phenomenon, defining the related concepts of *(up-)scaling* ("expanding a successful citizen science initiative in terms of the number of participants and the geographic extent") and *spreading* ("portability and replication of existing solutions, without a change of the actual scale of the activity in itself"). Clearly, economic factors are deeply embedded in both; some may be organisational / managerial in character and largely subject to human decisions; others, dictated from the outside. In general, "growth" is a key economic concept micro- and macro-economic-wise, relevant, of course, also to citizen science.

As said before, **voluntary work** is the standard pattern of citizen participation and contribution: "A key premise is that project organisers may be able to draw on *underused* [maybe "underpaid"?; note and italics of R.D.] human resources to advance research at relatively low cost" (Sauermann and Franzoni, 2015). These authors, building also on research done by many others, mention six types of **benefits** "from involving the crowd in the production of scientific research" (henceforth, partially quoted): (1) Contributing from intrinsic or social motivations rather than for financial compensation potentially allows project organisers to lower the cost of labor compared with traditional employment. (2) Speed advantages, to the extent that a large number of contributors work in parallel. (3) The large number of potential contributors enables projects to gain access to relatively rare skills and knowledge (also without scientific training). (4) Projects that require creative ideas and novel approaches typically benefit from rich and diverse knowledge inputs from a larger crowd with diverse competences and experiences. (5) Involving contributors across time and geographic space allows an increased coverage that is particularly important for observational studies. (6) Benefits for science education and advocacy.

All these benefits, however, translate into lower costs (and/or a higher benefit/cost ratio), overall, in some situations (projects) and less so, or not at all, in some others. In any case, as already mentioned, the achievement of **other (scientific, educational, other social, etc.) goals qualify the pure cost saving picture**. Additional developments come into play here, as outlined in Saurmann & Franzoni (op. cit.) in their study of projects under the Zooniverse umbrella, which need attention: uneven production ("a small share of contributors makes a large share of the contributions"); uneven extents and patterns of participation and contribution ("contributions are primarily driven by those who return for multiple days"; indeed, for many participation spans are very short and/or sporadic); unstable production ("contributions received by projects are highly volatile and critically depend on new users").

Research in other projects has often shown comparable findings to the above. Their meaning from our economic angle is principally a signal of caution: "free" work does not automatically mean zero cost, and the relation of work input to results ("the production function") is not clearly determined or fully predictable. Several additional factors affect the outcome, many of which are not economic in the usual sense – e.g., issues of **motivation and engagement** – but they should always be included in the economic analysis of projects involving volunteers. Sauermann et al. (2015), Theobald et al. (2015), Fauver (2016) and other authors referred (and not referred) in this section addressed the engagement and motivation factors in citizen science, the costs associated with engagement, the consequent effects on productivity, and other elements of economic significance. These issues have been analysed also in another Zooniverse-oriented research project led by the University of Portsmouth; *The wonders of the Zooniverse: Modelling and optimizing volunteer participation in online citizen science* (https://gtr.ukri.org/projects?ref=EP/K039784/1).

### 5.6.3 Project-specific aspects addressed in the citizen science literature

As written before, we are not deepening into any specific project's data, but we nevertheless refer below to some research on citizen science projects or groups of projects that we found illuminating in their handling of economic information, to which we may refer further on in our project for guidance and inspiration.

| Authors | Article's name | Knowledge area; essence as a citizen science endeavour |
|---|---|---|
| Bokhove et al., 2020 | A cost-effectiveness protocol for flood-mitigation plans based on Leeds' boxing day 2015 floods | Flooding, consequences mitigation. Cost-effectiveness analysis of flood mitigation, intended as a protocol to compare and choose between flood-mitigation scenarios in a quantifiable and visual manner, thereby offering better prospects of being understood by a wide audience, including citizens and city-council planners. |
| Haseler et al., 2019 | Cost-effective monitoring of large micro- and meso-litter in tidal and flood accumulation zones at south-western Baltic Sea beaches | Beach litter monitoring strategies. Differentiation between litter left at beaches and litter washed up onshore. Methods used are inexpensive, useful for volunteers, and can be carried out quickly (with limitations). |
| Toh et al., 2017 | A cost-effective approach to enhance scleractinian diversity on artificial shorelines | Seawalls to alleviate the impact of rising sea levels. Mitigating consequential loss of biodiversity. Newer approaches: transplanting certain corals on subtidal seawalls in Singapore with the help of volunteers (who seem to enable a 23% cost reduction). Synergy between the community and scientists reduces costs and benefits biodiversity. |
| Miskell et al., 2017 | Low-cost sensors and crowdsourced data: Observations of siting impacts on a network of air-quality instruments | Low-cost sensors offer the possibility of gathering high temporal and spatial resolution crowdsourced data-sets, improving understanding of individual and population exposure to air pollution. Crowdsourced approaches contribute to increase temporal and spatial resolution of air quality networks. |

| | | |
|---|---|---|
| Targetti et al., 2016 | Relating costs to the user value of farmland biodiversity measurements | Impact of agricultural management on global biodiversity. Besides the attention given to scientific effectiveness, relevant but less studied issues related to biodiversity measurements include the economic feasibility of monitoring programmes and the relevance of indicators for different end-users. |
| Targetti et al., 2014 | Estimating the cost of different strategies for measuring farmland biodiversity: Evidence from a Europe-wide field evaluation | Costs of farm-scale biodiversity monitoring. Assessment of resources consumed by the research units and cost estimation for the measurement of six biodiversity-related parameters. Estimating a standardised cost for an ordinary measurement of six parameters at farm-scale. Highlighting the cost differences between three strategies involving different potential actors (professional agencies, farmers, volunteers). |
| Nelms et al., 2017 | Marine anthropogenic litter on British beaches: A 10-year nationwide assessment using citizen science data | Marine ecology. Citizen science projects, whereby members of the public gather information, offer a low-cost method of collecting large volumes of data with considerable temporal and spatial coverage. Such projects raise awareness of environmental issues and can lead to positive changes in behaviours and attitudes. |
| Ambrose et al., 2019 | Spatial trends and drivers of marine debris accumulation on shorelines in South Eleuthera, The Bahamas using citizen science | Marine ecology. Best practices and challenges of citizen science projects on plastics in aquatic environments. "Citizen science is a cost-effective way to gather data over a large geographical range while simultaneously raising public awareness on the problem". |

### 5.6.4 Economic information in the context of CS Track

Having presented above the various economic concepts and variables that we currently deem relevant for our project (which, for the most part and as supported by existing research, are also relevant for citizen science in general), we refer below to some questions that we expect will guide us on the way to use this information profitably in CS Track. Even if discussions on those and other questions are underway, having identified the central concepts to work on will provide additional focus to those discussions, making them useful for the further determination of the elements that will have to be converted into real, measurable data for our multidisciplinary analysis. The questions, as we tentatively conceive them at this moment, refer to:

- What is the real weight of economic considerations in citizen science?

What kind of economic information would a user of our results be interested in? (Given also alternative sources of information, which may exist and be better suited for the user.)

- How could we approach the task of finding and supplying this information given the means and tools we will employ in our project's work?
- More specifically, how the use of web analytics could contribute to identifying economic data and making sense of it?

Questions of this kind can make the link between economic concepts and the generation of knowledge about the encompassing citizen science field, enriched with economic insight to all needed extent.

# 6 About categorising citizen science

*Michael Strähle & Christine Urban*

## 6.1 Typologies, categorisations, classifications in literature

As we have seen in Chapter 3 the term *citizen science* has different origins in quite different contexts that partly contradict each other. Since then, it has become an umbrella term covering so many different activities that has become impossible to find a definition that summarizes all different kinds of activities, in different settings with all different participant groups that are labelled with it. Hence, categorisations and typologies have been developed in order to get an overview of what the term means and to differentiate between the various forms of citizen science. Like other authors, categorisers implicitly or explicitly choose which activities they deem as citizen science and include into them in their schemes or leave them out. In the following we review some of the strategies to categorise or classify citizen science and examine their usefulness for answering CS Track's research questions.

Several scholars use the "degree" or "intensity" of involving "citizens" as a basis of their categorisation. Originally this approach was inspired by Arnstein's ladder of participation (Arnstein, 1969), which she developed for the context of urban planning. Such an approach is frequently normative, suggesting that more participation is always better, advocating the ideal that citizens should be involved in all stages of research and be in as much control as possible.

**Bonney et al.** (2009) choose the term "public participation in scientific research" or PPSR. In contrast to many other authors, they see "citizen science" as a different form of involving the public than "volunteer monitoring" and "community science". They also exclude participatory action research, which is sometimes included in citizen science definitions. (Bonney et al., 2009a, p. 16)

> *Citizen science is not the only model for public involvement in research, however. Other models include volunteer monitoring, community science, and participatory action research (Cornwall and Jewkes, 1995; Wilderman et al., 2004; Lawrence, 2006; Cooper et al., 2007; Ely, 2008). Often these models provide participants with a more comprehensive exposure to scientific methodology than do the projects typically operated by science institutions. For example, in most participatory action research, participants help to ask the research question, design the study, and interpret results in addition to collecting data. The various models and terms often blur, however, and defining each one precisely is challenging.* (Bonney et al., 2009a, p. 16)
>
> *Scientific investigations include many processes, steps, or activities in which the public can be involved. These include:*
>
> - *Choosing or defining questions for study*
> - *Gathering information and resources*
> - *Developing explanations (hypotheses) about possible answers to research questions*
> - *Designing data collection methodologies (both experimental and observational)*

- *Collecting data*
- *Analyzing data*
- *Interpreting data and drawing conclusions*
- *Disseminating conclusions*
- *Discussing results and asking new questions*

(Bonney et al., 2009a, p. 11)

"Disseminating conclusions" is listed among the activities defined as citizen science (Bonney et al., 2009a). Theoretically, this could make individuals who just spread the word on any research project as "citizen scientists", even if they had no other connection to a project.

The authors identify three major categories according to the "control that participants have over the different steps" in respect to "an educational perspective" (p. 17).

> *From an educational perspective, PPSR models differ chiefly by involving the public in these steps to varying degrees and by altering the amount of control that participants have over the different steps. For this report we have divided PPSR projects into three major categories:*
>
> 1) ***Contributory projects****, which are generally designed by scientists and for which members of the public primarily contribute data*
> 2) ***Collaborative projects****, which are generally designed by scientists and for which members of the public contribute data but also may help to refine project design, analyze data, or disseminate findings*
> 3) ***Co-created projects****, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all steps of the scientific process*
>
> (Bonney et al., 2009a, p. 11)

The authors developed these categories by assessing characteristics of participation in 10 projects; quite a low number. (They identify 5 contributory, 3 cooperative and 2 co-created projects.)

This scheme is quantifying the degree of involvement but without taking into account the percentage of participants who are involved to such a degree, which is inconsequent for a quantification. According to this model, the ideal of a "co-created" project would already be fulfilled if a few "members of the public" contribute to most or all steps in the research process. Correspondingly, if three or four citizens out of thousands are willing and resourceful enough to realise this intense degree of participation, it would be more "co-created" than a project that succeeds in involving most or all of their "citizens" in a few important steps. But who co-creates? The fewer take part in co-creating the whole research process, the more powerful they are compared to other participants. How can it be assured that "at least some members of the public participants" are independent from economic enterprises, political parties or other particular interests? The active involvement in "most or all steps of the scientific process" (Bonney et al. 2009a, p. 11) could constitute a considerable influence on what research questions are investigated and which are dropped. In extremis, in a project of wider impact a few participants could co-determine what data are collected, the methodology, and the results to be expected. Giving a few so much say could have unintended side effects. In other sectors of society than research and development, where public participation takes places, too, in policy making or urban planning, just to name two of them, there are vivid discussions about how legitimate and egalitarian such approaches really are. What is said above also holds true for other categorisations that are based on a ranking of intensity of participation.

In 2012 the scheme was further developed by **Shirk et al.** These authors are mostly the same that have written the original categorisation.

> ***Five Project Models***
>
> *We divide PPSR projects into five models based on degree of participation*
>
> - *Contractual projects, where communities ask professional researchers to conduct a specific scientific investigation and report on the results;*
> - *Contributory projects, which are generally designed by scientists and for which members of the public primarily contribute data;*
> - *Collaborative projects, which are generally designed by scientists and for which members of the public contribute data but also help to refine project design, analyze data, and/or disseminate findings;*
> - *Co-Created projects, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all aspects of the research process;*
>   *and*
> - *Collegial contributions, where non-credentialed individuals conduct research independently with varying degrees of expected recognition by institutionalized science and/or professionals."*
>
> (Shirk et al., 2012, p. 29)

While the categorisation by Bonney et al. (2009a) has been developed from an educational point of view, the now coined "models" constitute a "framework for deliberate design". Shirk et al (2012) make two additions: "*Contractual projects, where communities ask professional researchers to conduct a specific scientific investigation and report on the results*" are deemed as the lowest degree of participation. The highest degree of participation becomes "*collegial contributions, where non-credentialed individuals conduct research independently with varying degrees of expected recognition by institutionalized science and/or professionals*" (Shirk et al., 2012)

Again, the quantification by degree of participation is not convincing. If citizens can commission research (even if they do not pay for it), then they make a core decision: Determining what topics are chosen for investigation means determining how research funds are spent. Indirectly, these questions also determine the methodical choices and much of the rest of the project. Hence, the chronology of steps taken in a research process does not necessarily mirror the influence of citizen scientists on research. In other contexts, there would not be any doubt that those who decide how the budget is invested are in control and not those who do the work.

Another typology based on level of participation was developed by **Haklay** in 2013, which is focused on citizens contributing to geographic information in different ways. He suggests to differentiate between 4 levels of engagement, with crowdsourcing as the lowest and "extreme citizen science" as the highest level, which requires participation in "problem definition, data collection and analysis". (Haklay, 2013, p. 116)

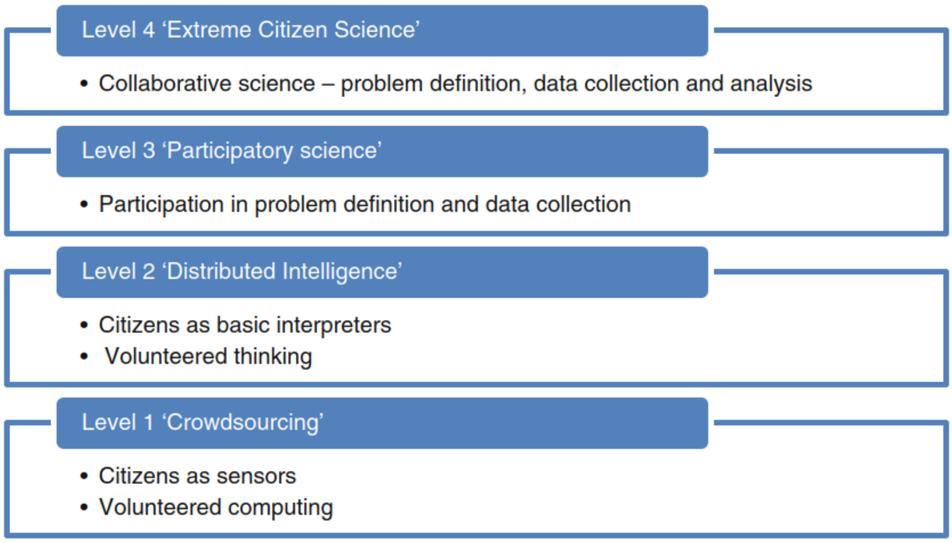
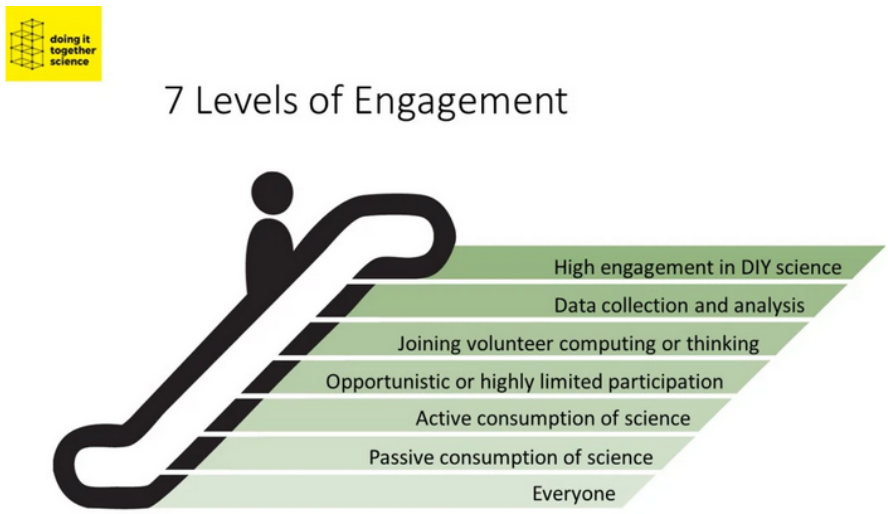



**Fig. 7.2** Levels of participation and engagement in citizen science projects

(Haklay, 2013, p. 116)

In his scheme, Haklay groups the activities of citizens engaging in research differently than Bonney and Shirk and their teams. However, the central problem remains the same: Apart from lay participants remaining more or less passive and contributing only resources, as Haklay depicts in his lowest level 1 ("crowdsourcing") and which many scholars do not label as citizen science at all, any ranking of citizen science activities remains a little artificial and highly normative. Later Haklay himself rejects ladders as he finds them judgmental: He adapts the escalator that was developed in the DITO project (Doing It Together Science) and which is not intended as a hierarchy: Being on the top of the escalator is not better than any other position, Haklay says in his blog (Haklay, 2018).




(Haklay, 2018)

The original escalator model had been developed 2017 by **Lotte Kleijssen, Pieter van Boheemen, Pauline Appels and Ester van der Geest** in the scope of the Horizon project DITO (Doing It Together Science) and presented in project deliverable D3.1.


*Figure 1 - The Escalator Model. The range of ways citizens participate in science*

(Kleijssen et al., 2017, p. 10)

> *A central model to DITOs is the 'escalator' of participation (Figure 1) in which a citizen in any walk of life may become aware of different levels of participation and choose that which is best for them, while being encouraged to try other levels - either toward higher or lower levels of engagement, in accordance to their needs, interests and availability of free time.* (Kleijssen et al. 2017, p. 9)

Hence, the escalator still maintains the hierarchy of participation levels from Arnstein, although it is less normative than other citizen science categorisations as it refrains from a judgement which level would be the best.

**Wiggins & Crowston** started their work with a systematic review of the typologies of Cooper et al., Wilderman and Bonney et al. and developed a categorisation which they refined later on.

They used landscape sampling and coded 80 facets of projects. By clustering, they

> *identified five mutually exclusive and exhaustive types of projects, which we labelled Action, Conservation, Investigation, Virtual and Education. Action projects employ volunteer-initiated participatory action research to encourage participant intervention in local concerns. Conservation projects address natural resource management goals, involving citizens in stewardship for outreach and increased scope. Investigation projects focus on scientific research goals in a physical setting, while Virtual projects have goals similar to Investigation projects, but are entirely ICT-mediated and differ in a number of other characteristics. Finally, Education projects make education and outreach primary goals […].* (Wiggins & Crowston 2011, p. 3428)

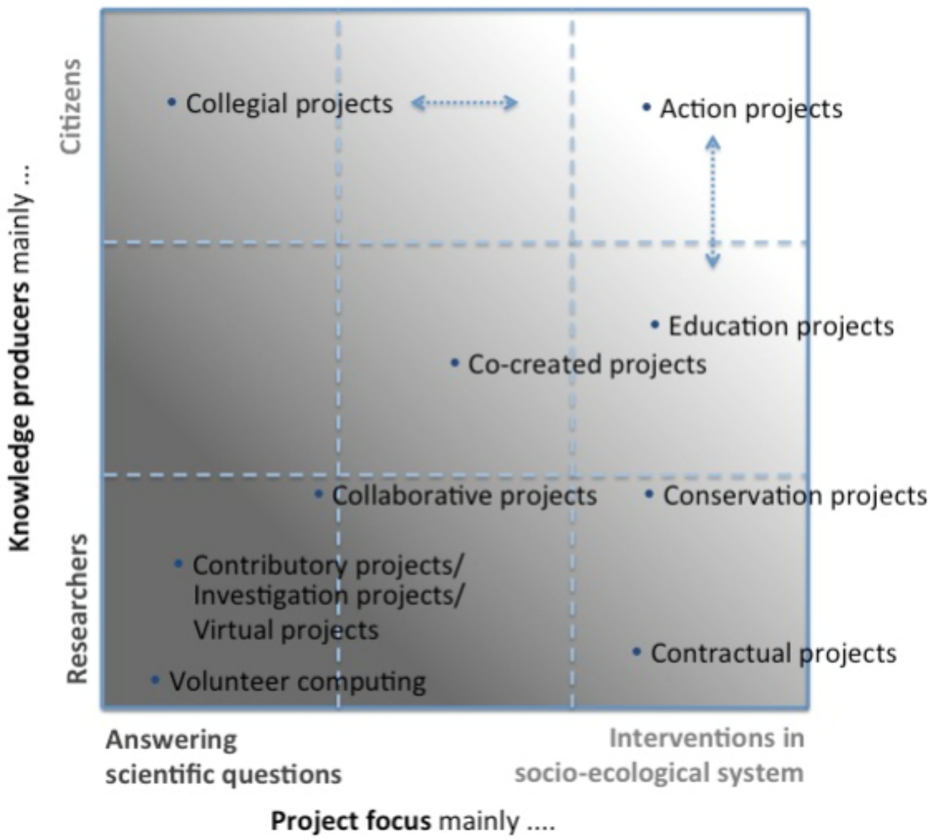
Instead of categorising citizen science projects according to participation structures, they decided to categorise them according to how volunteer participation in these projects is designed and managed. Grouping projects with common characteristics, they established two main categories: primary project goals and the degree of virtuality, respectively physical environment (Wiggins & Crowston 2012).

But the mutually exclusiveness remains questionable, mixes are not only possible, but also probable, and this first typology mixed dimensions. Why should a "virtual" project not contain elements of education? Virtual refers to the place where a project takes place, while "education" or "investigation" refers to project goals. It is also not plausible to assume only one primary goal in a project.

Two years later they developed a new and much more multi-layered categorisation that shows the complexity and diversity of citizen science. They analysed responses from 77 projects, and this time they categorised separately according to several different dimensions. They concluded:

> *We saw greater diversity among citizen science projects responding to our survey than is typically represented in stories about citizen science that appear in news media and popular science outlets. Although our sample included primarily observational projects in research areas related to ecology, there was an impressive range of types of participation, social opportunities, technologies in use, approaches to data validation, ways to measure contribution, and project goals.* (Wiggins & Crowston 2015)

**Schäfer and Kieslinger** follow a differentiated conception of typologies. Taking into account previous categorisations, they integrate different approaches by a two-dimensional scheme that allows to place project types between 2 axes, with the first one showing to what degree researchers or citizens produce knowledge and the second one the extent to which a project tries to answer research questions or to intervene in the social-economic system (Schäfer & Kieslinger, 2016, p. 3 et seq.). They adopt Bonney et al. (2009a)'s three levels of citizen science - contributory, collaborative and co-created citizen science. Goals like "education" or "conservation" are included, too. Following Shirk et al. (2012), they explain contractual projects as those where citizens delegate the research to be done.




(Schäfer & Kieslinger, 2016, p. 3)

A radically different approach is chosen by **Strasser et al**. in 2019: Based on a typology by Francois Grey, they distinguish five epistemic practices, which they call sensing, computing, analysing, self-reporting and making (Strasser et al. 2019). They regard this typology explicitly not a classification, as there can be hybrids between the practices, but as ideal types. The team shows some scepticism how far the different types can be grouped under the label citizen science:

> *This typology, like all typologies, has an agenda: by staying close to the actual knowledge practices of the actors, it avoids presupposing that they are all related and forms a thing called "citizen science.* (Strasser et al. 2019, p. 56)

Later it is explained that this typology includes practices their proponents do not necessarily label citizen science:

> *This typology also draws attention to practices not carried out under the banner of "citizen science," such as "participatory action research" and "community-based research," but that might nevertheless be essential to understanding public participation in the production of scientific knowledge.* (Strasser et al. 2019, p. 58)

In their essay on institutional oversight of citizen science, **Cooper et al. (2019)** classify projects in a different way for a very concrete and practical purpose that has important consequences: Their goal is to tackle the problem of institutional oversight to ensure the responsible conduct of institutional professional researchers involved in citizen science projects. They differentiate between research projects on three different dimensions: determining if a project is conducted by an institution, if humans are subjects of research and if personally identifiable is provided. They characterise 5 different types of projects and focus on type 4 projects as those which are wide-spread in citizen science:

| | Institutional Research | | | | Non-Institutional Research |
|---|---|---|---|---|---|
| Subject Matter | Humans | Humans | Not Humans | Not Humans | All subjects |
| PII | Private | Open | No | Yes | Yes/No |
| Type | 1 | 2 | 3 | 4 | 5 |

**Figure 1:** Categories of citizen science projects. We categorized projects through several levels, first based on whether they are institutional research, second on whether the subject matter was human subjects or other subjects, and third related to the handling of personally identifiable information (PII).

(Cooper et al., 2019, p. 2)

Only the first four types of activities take place in an institutional frame: Type 1 describes projects in which participants remain anonymous and contribute personal data to classical research projects, such as responding to questionnaires or online tests. In Type 2 projects citizens have two roles, they are subjects of research and active citizen scientists at the same time. Type 3 projects are those in which citizens carry out research (or related tasks), but are not subjected to research and they do not contribute personal data because they can participate anonymously. Type 4 projects are similar to Type 3 projects, although citizen scientists are not subjects of research - they give access to personal data by participation. Either their contact data are needed to organise the project, or they provide geolocated data without which the usefulness of their observations or collected data would be compromised (Cooper et al., 2019, p. 2 et seq.).

## 6.2 About typologies: Is categorising citizen science possible?

**Prainsack (2014)** shows the difficulties, if not the impossibility, to classify citizen science due to the many aspects that would have to be taken into account.

> *What all citizen science initiatives share in common is that they involve the participation of non-professional scientists at the stage of funding, data collection/generation, analysis, interpretation, application, dissemination, or evaluation. There are great differences, however, in the activities and formats typically subsumed under the label of citizen science. While some are led by*

*non-professional scientists at every stage of the project, in others, 'citizen scientists' have no decision-making power with regard to core strategies but they contribute merely as data collectors, or even only as funders.* (Prainsack, 2014, p. 6)

Not a typology, but a list of important questions concerning different dimensions of activities labelled as citizen science is presented by Prainsack (2014). She poses 19 questions in respect to the dimensions: coordination, participation, community, evaluation, openness and entrepreneurship:

***Coordination: Who has influence in:***
*1. Agenda setting*
*2. Determining the terms of the execution of the idea/procedural aspects*
*3. Deciding what results are (and what 'good' results are)*
*4. Deciding what will be done with results*
*5. Deciding on intellectual property questions*

***Participation***
*6. Who participates (demographic and social parameters of those who participate)? Why, and how do they participate?*
*7. How much, and what kind of, training, skill, or expertise is required to participate in this project?*
*8. Are there cultural, institutional, or other differences in perception and framing of core issues and stakes?*

***Community***
*9. What forms of community pre-exist this project, if any? Which new communities does the project facilitate or give rise to? What is the constitutive factor for the feeling of belonging on the side of the participants?*

***Evaluation:***
*10. How and by whom is it decided what good outcomes are?*
*11. What happens to the results of these evaluations?*

***Openness:***
*12. Do participants in the project have access to the core datasets?*
*13. Can participants in the project edit the core datasets?*
*14. Is the contribution of participants adequately acknowledged in published materials?*
*15. Are datasets made publicly accessible (open source/open access)?*
*16. Are main findings made publicly accessible (open source/open access)?*

***Entrepreneurship:***
*17. How is the project funded?*
*18. What is the role of for-profit entities in this project? Are these small, medium-sized, or large entities, and where are they located?*
*19. How are for-profit and other interests aligned in this project (and/or do they conflict, and where?)*

(Prainsack, 2014, p. 7)

Her questions concern mostly questions of power and influence of different actors in citizen science projects, including questions of evaluation and involvement of for-profit organisations.

Concerning the evaluation of outcomes, it is the question if or in what respect the results of citizen science should differ from the evaluation of "traditional" research and how the problem is solved for evaluating research in general. How to measure quality of research is a research area of its own, and there are many voices who see an urgent need for improvement.

In a multivariate analysis of hundreds of environmental and ecological citizen science projects, **Pocock et al. (2017)** did not find defined clusters (with the exception of computer-based projects). Instead, they found a broad diversity of approaches:

> *It seems that any discrete 'classification' or 'typology' of citizen science is one that is imposed upon the diversity of citizen science, rather than being a natural explanation emerging from it. This explains why it is so challenging to create a detailed typology or classification of citizen science or succinctly provide guidance on selecting citizen science approaches [30].* (Pocock et al. 2017, p. 10)

## Conclusion

Citizen science, at least in Europe, has turned into an umbrella term for a lot of very different practices. What these have in common is only that they involve people into research who come from different professions or different disciplines than the project deals with. Several scholars have tried to solve the problem with defining the term "citizen science" by differentiating between different forms citizen science can have. They developed categorisations and typologies mostly for theoretical discussion and advancement. However, these categorisations and typologies are too general to assess real research projects that engage with publics. Other scholars do not agree that a typology is even possible (e.g. Prainsack, 2014, Pocock et al., 2019). Any typology can only concentrate on one or few facets of citizen science, leaving out other, equally important dimensions.

## Questioning the term "citizen science project"

Most categorisations and typologies refer to "citizen science projects". This implicates a dichotomy between traditional research projects and projects in which lay persons are involved. After reviewing categorisations in literature, we question calling entire projects "citizen science" or "not citizen science". In reality such strict distinctions do not hold. Most existing "citizen science projects" do more than involve citizens in science or innovation. As citizen science contains the term "science", from a linguistic perspective, only those aspects or elements of a project that are related to science can be called citizen science.

For instance, when citizens in a project carry out nature conservation activities on the one hand and collect data for analysis on the other, then the project partially qualifies as environment protection and partially as citizen science. *Plastic Pirates* is an example for such a project: It combines picking up plastic litter with gathering data. The first activity is not a scientific one *per se*, hence only the second falls under "citizen science activity". Another example is an initiative aiming at improving a community: While much of the project may involve neighbourhood support, the project might also employ citizen science activities to gain knowledge that is important for the project. Examples for this are citizen initiatives in Japan that, after the Fukushima incident, a nuclear disaster caused by an earthquake and a tsunami, began testing everything - e.g. food, water, soil, grass and dust - for radioactivity because they did not trust the official numbers. With mothers as their main proponents, they developed community services. In one case they created a medical care centre whose purpose goes beyond dealing with the aftermaths of the nuclear disaster. The main objective is and was not to contribute to scientific research but to safeguard their families and communities (Kenens et al., 2020; Kimura, 2016). The same is true for a public health project that aims at changing people's living styles and analysing data on them. Only a part of the project falls under science or with citizen science. An initiative thriving for political change and engaging in citizen science to scientifically support their demands, does not turn into citizen science as a whole. It remains political activism that also has an element of citizen science. Citizen science seems to be very often one element of a project among others. According to scholars "co-created" or "extreme citizen science" are rare (see Chapter 6). Even if citizen science is the most prominent characteristic of a project, it rarely might be the only one. Instead of asking if a project is citizen science or not, it might be clearer to ask: Which parts of a project are citizen science and which are something else? And which other activities are often combined with citizen science? Additionally, projects can have more than one part that falls under the umbrella citizen science, and it may be necessary to evaluate them separately, as there are different potential benefits, caveats, barriers, enablers and/or limitations; different guidelines can apply and best practices discussed for them.

# 7 Categorising citizen science in CS Track

*Michael Strähle & Christine Urban*

## 7.1 Why categorisations?

While we were working on it, we saw that fully distinct categories are simply not feasible in citizen science. The field is too broad and there are too many dimensions along which citizen science can be characterised. Previous attempts categorise often along one dimension only (for example degree of participation) and sometimes different dimensions are mixed. As Strasser et al. (2019) state, the existing categorisations and typologies should be regarded rather as ideal types (Strasser et. al., 2019) (The term ideal type has been coined by Max Weber and is used in sociology to describe a pure type showing a bundle of characteristics that are often connected to it, but which probably does not exist in reality.) Ideal types seldom exist in reality or not at all.

CS Track aims at investigating specific questions about benefits and caveats, barriers and enablers, incentives and disincentives in citizen science. These questions cannot be answered by looking at clusters of citizen science projects or at classifications in respect to one or few dimensions. Here, the devil is often in the detail, if a type of citizen science differs in one single characteristic from another, this can change the whole picture in respect to the above issues.

We distinguish four main areas and set up a list of characteristics, but refrained from creating something new, if there existed useful and applicable classifications, which were recognised on an international level. This is the case for instance with research areas and disciplines. Inventing something new would have jeopardised comparability between "traditional" research projects and that integrate citizen science activities. Classifications of academic disciplines and fields of research already exist, and it has taken the hard work of specialists to develop them. Accordingly it was rather a question of finding out, which of them would serve best the objectives of CS Track and fit best into the structure of the database that is created in Work Package 2.

Accuracy demands that one does not allocate a project as a whole to one discipline. Instead, one has to distinguish between at least 3 aspects:

1. disciplinary competences in project organisation teams
2. self-categorisation of the project by its organisers and
3. Reception/acceptance by different academic communities. This can be indicated by publications, conferences, specific social media in academia, etc. (apart from those dealing mainly with citizen science)

To give a fictional example: A group of professional biologists might regard their citizen science project as a research activity in the field of linguistics, while professional linguistics could be (rightfully or not) critical about the used methods and conclusions and the respective research communities would not accept the outcomes.

Distinctions based on research areas and/or disciplines meet some limitations. Not only because many citizen science activities are carried out interdisciplinary and not only because research traditions in different parts of the world make disciplines and areas not always comparable. There is another reason: While concrete tasks/activities for citizen scientists can be very similar across quite different research areas and disciplines, they can radically differ within the same discipline or research area.

One can see a lot of similarities between finding ragweed (biology), rocks (mineralogy), buildings (architecture), old tools (history). Hence the question to which discipline or research field these activities belong could be relatively small compared to other questions. On the other hand, generalisations in social and cultural sciences across so different methods as analysing texts, interviewing concerned persons, seeking historic evidence in archives, observing behaviour in crowds, surveys or interpreting pictures or films are impossible.

One of the main questions in citizen science is the question of responsibility: Do “citizen scientists” deal with sensitive data of others and how can these others be protected, do they share their own private data and how much are they aware of this, is there direct or indirect contact rare animals and environments – these are more central questions.

Although such ethical and privacy issues can appear much more often in one discipline/field than in another, no general statements on citizen science in “health”, “social sciences”, “biodiversity” or “environment” can be made in this respect.

The same is true for many other dimensions: The concrete project has to be checked against multiple factors to come to conclusions about potential benefits and caveats, but also what concerns incentives, disincentives, barriers or enablers.

Distinguishing between research areas and disciplines is necessary to get some indication of the quality of research. Do professional scientists contribute their expertise to a citizen science activity? If not, they would participate as a citizen scientist (given the understanding that “citizen scientist” indicates someone with no scientific training relevant to the research project). It would be interesting to investigate, how seldom/often citizen science organisers from other than relevant fields take on which role with what professional background. It is also of interest from which fields professionals, who organise citizen science, come and how it impacts on their reputation in different fields. Can they hope to establish a career or, on the contrary, would engaging professionally in citizen science rather distract them from building a career? We would hesitate to generalise this across disciplines.

## 7.2 The Activities & Dimensions Grid of Citizen Science

### 7.2.1 Explanation

The Activities & Dimensions Grid of Citizen Science is based on four distinguished areas of citizen science activities. Depending on circumstances, the respective activities can be different in nature and impact; and their potential benefits and caveats, barriers and enablers, and incentives and disincentives for them - all these are research topics of CS Track - depend on a context they are part of. To mirror differences in context and circumstances, it was decided to assign different dimensions to each activity. Such a differentiation allows for targeted evaluations of citizen science activities and for drafting context-sensitive guidelines and recommendations. Furthermore, closer attention to contexts and differences facilitates a better understanding of actual and potential ethical issues.

The possibilities to categorise citizen science projects are endless. Hence this list of dimensions to distinguish between project characteristics may be enhanced by additions if necessary.

### 7.2.2 Main areas

We have identified 4 general areas that are in some respect different enough to make overlaps relatively unlikely, but of course they exist.

**Area 1: Input for research policy**

| | |
|---|---|
| Main objectives | Consultations on topics to be researched (research agenda setting), development of funding schemes, etc. |
| Examples | Public consultations, citizen panels, Play Decide games, World Cafés, etc. |
| Comments | Research policies are part of politics, so they have to be examined in terms of legitimacy and democratic standards. |

**Area 2: Taking part in research projects**

| | |
|---|---|
| Main objectives | The same as in science in general and related to improving scientific knowledge.<br>(Sometimes additional objectives are given, such as education, personal development, and the process itself, but the research goal is presented as the most important.) |
| Examples | Any activity of citizens is possible at any stage of research. This broad range can include formulating research questions, observation, taking samples, setting up libraries, recognising patterns, deciphering handwritten documents, carrying out experiments, solving logical puzzles, and many more. |
| Comment | This is the largest area of citizen science. |

**Area 3: Development and innovation**

| | |
|---|---|
| Main objectives | A new or improved specific product |
| Examples | Developing technical devices, software, hardware, chemical compound, a testing instrument, a tool, even genetically modified organisms. Citizens can give feedback on the usability of products and work together with technicians and developers, combine existing technical parts to create an innovation, build something from scratch, etc. This area comprises also parts of the DIY movement and DIY biology, which can vary from conducting experiments and self-examination to self-improvement and sometimes even genetic engineering. |
| Comments | The boundaries between science and engineering are blurry. |

**Area 4: School projects with minors**

| | |
|---|---|
| Main objectives | Science education of minors according to a broader curriculum. Other outcomes are targeted, too, but the training of children and youth remains first priority. |
| Examples | Principally the areas 1-3 can be and are conducted in schools, but are adapted to education as a main goal. |
| Comments | It was considered to include adult education into the area and call it curriculum-based citizen science. We decided against it, because in a university context research and education are intertwined. Additionally, the school area is specific by addressing the human right of each child to receive a good education. |

### 7.2.3 Categorisation by the dimension “activity”

For each activity, dimensions have to be regarded separately. For a project that comprises different activities an estimation of the rough proportions of the activities has to be made, preferably this information should be given by the project organisers. For example, project activities could consist to 90% of data collection, of which 10%, i.e. 9% of all activities, are done in school projects. Apart from that, each activity has to be regarded separately.

Contributing data encompasses quite different things from, e.g. providing one's personal data to actively collecting data by reporting observations. The authors therefore distinguished between different forms of contributing data. First of all, the authors distinguished between contributions that are characterised by a more passive and ones that are characterised by a more active role of the contributors. "More" indicates that also providing one's personal data might require some activity. If one donates a DNA sample, some activity is required to get the sample. If one provides personal data automatically, e.g. via a tracking device, no wilful activity is required. Passive participation was categorised under "Providing resources" and so was providing personal data. This category includes providing personal data, providing infrastructure (e.g. computing power) and donating materials and tools. In respect to active contributions of data the authors distinguished between data collection, data preparation & processing, and making experiments. Altogether, the authors distinguished between seven forms of data collection: Observation, reporting, taking samples, measuring and counting, searching for artefacts, conducting interviews, and supporting data collection. In respect to data preparation & processing the authors distinguished four forms: Classifying; characterising, describing, localising; matching data; and transcribing.

| ***ACTIVITIES-DIMENSION GRID OF CITIZEN SCIENCE (ADG-CS)*** *Derived from categorisations, typologies, classifications and listed open questions found in literature* | **Area 1 Research policy** | **Area 2 Participating in research** | | | | | | | | | | | **Area 3 D & I** | | **Area 4 School** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Deliberation, consultation …** | **Determining research questions** | **Research design** | **Data collection** | **Data preparation & processing** | **Retrieval of scientific** | **Experimenting** | **Knowledge** | **Analysis & problem** | **Reviewing &** | **Action research** | **Passive participation** | **Technical development** | **DIY biology** | **All activities in Areas 0-3 are possible.** |
| | | | | | | | | | | | | | | | |
| ***Location of participation*** | | | | | | | | | | | | | | | |
| **Physical place** | | | | | | | | | | | | | | | |
| At home, working place, garden … | | | | | | | | | | | | | | | |
| A separate institution (laboratory, garage …) | | | | | | | | | | | | | | | |
| Outside in unspecific environments | | | | | | | | | | | | | | | |
| Outside in dangerous environments | | | | | | | | | | | | | | | |
| Sensible biotopes (Marshes, wildlife parks, …) | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **ICT environment** | | | | | | | | | | | | | | | |
| Online platforms | | | | | | | | | | | | | | | |
| Forums | | | | | | | | | | | | | | | |
| Social media (Twitter, …) | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Location not determined** | | | | | | | | | | | | | | | |

| | Consult-DeliB | Det. quetstions | Research design | Data collection | Data preparati | Retrieval of sci. lit. | Experime nting | Knowl. MGT | Analysis & problem | Review. & evaluatin | Action research | Passive part. | Tec. develpm. | DIY bio | 1-3 in school |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Requirements for participation*** | | | | | | | | | | | | | | | |
| **Material** | | | | | | | | | | | | | | | |
| Smartphones | | | | | | | | | | | | | | | |
| Specific software | | | | | | | | | | | | | | | |
| Measuring devices (sensors, …) | | | | | | | | | | | | | | | |
| Laboratory equipment | | | | | | | | | | | | | | | |
| Optical instrument (microscope, telescope, etc.) | | | | | | | | | | | | | | | |
| Other special devices | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Non-material** | | | | | | | | | | | | | | | |
| Certain skills or knowledge | | | | | | | | | | | | | | | |
| Degree of experience | | | | | | | | | | | | | | | |
| Minimum level of education (e.g. high school degree) | | | | | | | | | | | | | | | |
| University study (ongoing) | | | | | | | | | | | | | | | |
| Specific training | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Scale of the citizen science project*** | | | | | | | | | | | | | | | |
| **Number of participating "citizen scientists"** | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Intensity of unpaid work** | | | | | | | | | | | | | | | |
| Working hours per month & duration by month | | | | | | | | | | | | | | | |

| | Consult-DeliB | Det. quetstions | Research design | Data collection | Data preparati | Retrieval of sci. lit. | Experime nting | Knowl. MGT | Analysis & problem | Review. & evaluatin | Action research | Passive part. | Tec. develpm. | DIY bio | 1-3 in school |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Characteristics of country*** | | | | | | | | | | | | | | | |
| Human development Index (UN) | | | | | | | | | | | | | | | |
| Life expectancy below EU Member States (WHO) | | | | | | | | | | | | | | | |
| Democracy (EIU) | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Geographic coverage*** | | | | | | | | | | | | | | | |
| Local (L), Regional (R), National (N), Global (G), EU | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Beings and/or objects dealt with*** | | | | | | | | | | | | | | | |
| **Objects/non-sentient beings** | | | | | | | | | | | | | | | |
| Undamagable or ordinary inanimate objects/non-sentient beings | | | | | | | | | | | | | | | |
| Damagable, rare or valuable objects/ beings | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Sentient beings** | | | | | | | | | | | | | | | |
| Domestic animals | | | | | | | | | | | | | | | |
| Wildlife | | | | | | | | | | | | | | | |
| Endangered or rare species (red list?) | | | | | | | | | | | | | | | |
| *(Indirect damage possible ---> protected habitats ----> see: locations.)* | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Humans** | | | | | | | | | | | | | | | |
| Identifiable humans | | | | | | | | | | | | | | | |
| Non-identifiable humans | | | | | | | | | | | | | | | |

| | Consult-DeliB | Det. quetstions | Research design | Data collection | Data preparati | Retrieval of sci. lit. | Experime nting | Knowl. MGT | Analysis & problem | Review. & evaluatin | Action research | Passive part. | Tec. develpm. | DIY bio | 1-3 in school |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Funding*** | | | | | | | | | | | | | | | |
| Citizens themselves (no external funding). | | | | | | | | | | | | | | | |
| Crowdfunding | | | | | | | | | | | | | | | |
| SMEs, their associations or organisations | | | | | | | | | | | | | | | |
| Large enterprises, their associations or organisations | | | | | | | | | | | | | | | |
| Government (agency, non-military) | | | | | | | | | | | | | | | |
| Military | | | | | | | | | | | | | | | |
| Publicly funded organisations | | | | | | | | | | | | | | | |
| Political parties, religious or other ideologic organisations | | | | | | | | | | | | | | | |
| Private persons of wealth | | | | | | | | | | | | | | | |
| Socio-economic enterprise/s | | | | | | | | | | | | | | | |
| Civil society organisation/s | | | | | | | | | | | | | | | |
| Philanthropic foundations | | | | | | | | | | | | | | | |
| European Commission | | | | | | | | | | | | | | | |
| UN organisation or similar international organisation | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Initiators of citizen science*** | | | | | | | | | | | | | | | |
| Citizens with no academic education in the field | | | | | | | | | | | | | | | |
| Researchers in the field or research organisations | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Organisers (Who runs the project?)*** | | | | | | | | | | | | | | | |
| See groups in "funding". | | | | | | | | | | | | | | | |

| | Consult-DeliB | Det. quetstions | Research design | Data collection | Data preparati | Retrieval of sci. lit. | Experime nting | Knowl. MGT | Analysis & problem | Review. & evaluatin | Action research | Passive part. | Tec. develpm. | DIY bio | 1-3 in school |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Citizen scientists are known to*** | | | | | | | | | | | | | | | |
| Organisers | | | | | | | | | | | | | | | |
| Everybody in the project | | | | | | | | | | | | | | | |
| Publicly | | | | | | | | | | | | | | | |
| None of them (anonymous) | | | | | | | | | | | | | | | |
| Unknown issue | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Partners cooperating as citizen scientists*** | | | | | | | | | | | | | | | |
| Individual citizens | | | | | | | | | | | | | | | |
| NPOs | | | | | | | | | | | | | | | |
| Educational institutions | | | | | | | | | | | | | | | |
| Other institutions? | | | | | | | | | | | | | | | |
| Communities/civil initiatives | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Individuals as citizen scientist(s)*** | | | | | | | | | | | | | | | |
| Lay persons in the field | | | | | | | | | | | | | | | |
| Non-academic experts in the field | | | | | | | | | | | | | | | |
| Sometimes also: Participants with ongoing (or partially completed) university studies in the field | | | | | | | | | | | | | | | |
| Users | | | | | | | | | | | | | | | |
| Makers and developers | | | | | | | | | | | | | | | |
| School students and pupils (most <18 years old) | | | | | | | | | | | | | | | |

| | Consult-DeliB | Det. quetstions | Research design | Data collection | Data preparati | Retrieval of sci. lit. | Experime nting | Knowl. MGT | Analysis & problem | Review. & evaluatin | Action research | Passive part. | Tec. develpm. | DIY bio | 1-3 in school |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Individuals as traditional scientist(s)*** | | | | | | | | | | | | | | | |
| No "traditional scientists" involved | | | | | | | | | | | | | | | |
| Professional researchers/scientists | | | | | | | | | | | | | | | |
| Students in a relevant field. | | | | | | | | | | | | | | | |
| Persons who partly completed studies in a field relevant to the project | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Topic areas and/or disciplines*** | | | | | | | | | | | | | | | |
| 1. Disciplinary competences in project organisation teams | | | | | | | | | | | | | | | |
| 2. Self-categorisation of the project by its organisers | | | | | | | | | | | | | | | |
| 3. Categorisation by research funders, publishers, and other researchers | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ***Incentives and remunerations promised*** | | | | | | | | | | | | | | | |
| None | | | | | | | | | | | | | | | |
| Symbolic (Price, worthless certificate, medals ...) | | | | | | | | | | | | | | | |
| Monetary remuneration | | | | | | | | | | | | | | | |
| Certificate on education/experience | | | | | | | | | | | | | | | |
| Recognition by naming | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | |

### 7.2.4 Explanations and suggestions to operationalize

In the following, the authors describe the citizen science activities they identified and give some examples of how they may impact on the research questions in CS Track. The suggestions for operationalisations have been developed for the ideal case that these facts about projects are available. At the moment, most projects give much less information about the characteristics of their activities. If citizen science activities are considered for funding or to be supported otherwise, at best the following dimensions and activities should be known.

**Activities: Operationalisation & important aspects to consider**

| | **Suggestion for operationalisation** | **Important aspects (exemplary)** |
|---|---|---|
| **Area 1: Research policy** | | |
| Deliberation, consultation, etc. | | Inclusion and democratic structures of high importance as research policies might be influenced. |
| **Area 2: Participating in research** | | |
| Determining research questions | Y/N If YES →% | Inclusion and democratic structures of high importance. |
| Research design | Y/N If YES →% | Inclusion and democratic structures of high importance. |
| Data collection | Y/N If YES →% | A broad range of low- to high skilled activities often performed by volunteers. |
| Data preparation & processing | Y/N If YES →% | See data collection |
| Retrieval of scientific literature | Y/N If YES →% | See data collection |
| Experimenting | Y/N If YES →% | See data collection |
| Knowledge management | Y/N If YES →% | See data collection |
| Analysis & problem solving | Y/N If YES →% | See data collection |
| Reviewing & evaluating | Y/N If YES →% | Inclusion and democratic structures of high importance. |

| | | |
|---|---|---|
| Action research | Y/N If YES →% | Specific skills of those who apply methods of group dynamics to avoid risk of psychological damage. |
| Passive participation | Y/N If YES →% | Many scholars do not consider this as CS. |
| **Area 3: Development & Innovation** | | |
| Technical development | | Questions of ownership in case of marketable products. |
| DIY biology | | Widely debated when it comes to genetic engineering or health topics. |
| **Area 4: School projects** | | |
| All activities in Areas 0-3 are possible. | | Activities in Area 1-3 are or can be conducted in schools but with a presumably more rigorous priority of school education of minors. |

In the following table the authors exemplify citizen science activities they have found in scientific literature and project databases. These are not clear-cut activities, although at first sight they seemingly are. Take for example the Transcribe Bentham project. Jeremy Bentham was a British philosopher in the 19th century with an extensive legacy consisting of handwritten manuscripts. These manuscripts are transcribed - or shall one say 'deciphered'? - by volunteers. The transcripts form the basis for the critical edition of Bentham's collected works. Bentham is notorious for the poor legibility of his handwriting. One can imagine that transcribing his manuscripts is a demanding task that requires some understanding of such handwritten manuscripts, also of the language Bentham used. Taken this into account, is transcribing Bentham's manuscripts "only" transcribing or is it also decoding? Probably both, but are these two distinct activities? Probably not, but in other projects decoding, deciphering or transcribing could be distinct activities.

**Activities: Examples**

| | **Specific activity/task** | **Examples** |
|---|---|---|
| **Area 1: Research policy** | | |
| | Participating in public consultation | |
| | Participating in deliberative formats | E.g. citizen panels, Wisdom Councils |

| Area 2: Participating in research | | |
|---|---|---|
| Project development | Determining research questions | Formulating research questions deciding what problems are researched. |
| | Research design | All other contributions to research development other than determining research questions. |
| Data collection | Observation | E.g. stars, animal behaviour |
| | Reporting | E.g. road kills, sighting of rare animals |
| | Taking samples | E.g. from a river, from earth, or animal droppings |
| | Measuring and counting | E.g. droppings of animals, people crossing a place at certain times |
| | Searching for artefacts | E.g. historic documents, photos, films, archaeologic excavations |
| | Conducting interviews | |
| | Supporting data collection | E.g. place camera traps |
| Data preparation & processing | Classifying | E.g. identify species, categorising pictures in a journal |
| | Characterising, describing, localising | E.g. identify the location of photos, films |
| | Matching data | E.g. find out to which object data belong |
| | Transcribing | E.g. decipher handwritten documents, make transcripts of interviews |
| Retrieval of scientific literature | Searching in scientific libraries and databases | |
| Experimenting | Carrying out experiments | E.g. raising plants under different conditions, cleaning effect of chemicals |
| Knowledge management | Setting up, running scientific libraries, archives, etc. | E.g. museums, online libraries, wikis |
| Analysis & problem solving | Solving theoretical problems | E.g. logical, mathematical problems |

| | | |
|---|---|---|
| | Decoding | E.g. historic languages, scripts |
| | Serious gaming | E.g. online puzzles |
| | Pattern recognition | E.g. photos, numbers |
| Reviewing & evaluating | Two-way discussion of results | (Not negotiation of desired results) |
| | Detection of flaws concerning methods, conclusions, research design, etc. | |
| | Detection of conflicts of interest | |
| Action research | Sometimes labelled as citizen science | |
| Passive participation | Giving personal data | For instance, citizen scientists are probands, interviewees, fill in questionnaires, etc. |
| | Providing infrastructure | E.g. providing computer space |
| | Donating material and tools | |
| **Area 3: Development & Innovation** | | |
| | Designing | E.g. taking part in ideation, drawing construction plans |
| | Providing user feedback | |
| | Building prototypes | |
| | Programming and coding | E.g. software, codes for devices |
| | DIY biology | E.g. self-experimenting, in the extreme implants and genetic engineering |
| **Area 4: School projects** | | |
| | | All above mentioned activities can take place in school settings with (mostly) minors in the role of citizen scientists. |

**Dimensions: Operationalisation & important aspects to consider**

| Dimension | Suggestion for operationalisation | Important aspects (exemplary) |
|---|---|---|
| **Location of participation** | | |
| ***Physical place*** | | |
| At home, working place, garden … | Y/N ---> % of project? | |
| A separate institution (laboratory, garage …) | Y/N ---> % of project? | |
| Outside in unspecific environments | Y/N ---> % of project? | |
| Outside in dangerous environments | Y/N ---> % of project? | |
| Sensible biotopes (marshes, wildlife parks, …) | Y/N ---> % of project? | |
| | | Depending on the physical location, different aspects need attention: precaution to maintain privacy, when personal data (location data, date and time stamps, etc.) are submitted in the first case, in the last case caution to avoid harm is required. |
| ***ICT environment*** | | Privacy issues to be considered. |
| Online platforms | Y/N ---> % of project? | |
| Forums | Y/N ---> % of project? | |
| Social media (Twitter, …) | Y/N ---> % of project? | |
| Other | Y/N ---> % of project? | |
| ***Location not determined*** | Y/N ---> % of project? | Privacy issues to be considered. |
| **Requirements for participation** | | |
| ***Material*** | | |
| Smartphones | Y/N | |
| Specific software | Y/N | |
| Measuring devices (sensors, etc.) | Y/N | |
| Laboratory equipment | Y/N | |

| | | |
|---|---|---|
| Optical instrument (microscope, telescope, etc.) | Y/N | |
| Other special devices | Y/N | |
| ***Non-material*** | | |
| Certain skills or knowledge | Y/N | |
| Degree of experience | Hours per month * duration (in months) | |
| Minimum level of education (e.g. high school degree) | Y/N | |
| University study (ongoing) | Hours per month * duration (in months) | |
| Specific training | Y/N | |
| | | It could be offered to acquire specific skills or experiences. Required equipment can exclude those who cannot afford it. Additionally, if state of the art computers and smartphones are necessary, this might trigger buying new ones, which would go against environmental sustainability. Potential countermeasures are to lend devices to citizen scientists, rely on DIY equipment, and/or to design activities in a way that older equipment is suitable. |
| **Scale of the citizen science project** | | |
| ***Number of participating "citizen scientists"*** | Absolute number or range (below 10, 11-100, etc.) | |
| ***Intensity of unpaid work*** | | |
| Working hours per month & duration by month | Working hours per month * duration (in months) (0,1 h p.m. * 12 m =1,2 h) | |
| | | Exploitation? Replacing paid work? These questions become relevant with a certain amount of unpaid work. Activities can be scaled between a few minutes per week and almost full-time volunteering. |

| | | |
|---|---|---|
| ***Characteristics of country*** | | |
| Human development Index below EU Member States (UN) | Y/N | |
| Life expectancy below EU Member States (WHO) | Y/N | |
| Democracy below EU Member States (EIU) | Y/N | |
| | | Specific considerations are needed when projects are conducted in poor countries and/or non-democratic regimes. Such countries can be identified with one of these three indices. Organisers from western democracies may need specific education or to cooperate with experts in development cooperation. Specific risks of citizens in these countries may need informed awareness and attention, too. |
| ***Geographic coverage*** | | |
| Local (L), Regional (R), National (N), Global (G), EU | Specify L, R, N, G or EU | Local projects could have more direct impact on the lives of citizen scientists. |
| **Beings and/or objects dealt with** | | |
| ***Objects/non-sentient beings*** | | |
| Undamageable or ordinary inanimate objects/non-sentient beings | Y/N | |
| Damageable, rare or valuable objects/non-sentient beings | Y/N | |
| ***Sentient beings*** | | Animal protection issues |
| Domestic animals | Y/N | |
| Wildlife | Y/N | |
| Endangered or rare species (Red List?) | Y/N | |
| ***Humans*** | | |
| Identifiable humans | Y/N | |

| | | |
|---|---|---|
| Non-identifiable humans | Y/N | |
| | | This dimension has strong consequences on possible harm that could be done by non-learned inexperienced lay persons and the degree of responsibility given or delegated to them. It takes also into consideration how persons could be held responsible in case of misconduct if they do not breach the law. Misconduct by traditional scientists can be sanctioned in scientific communities and the person concerned risks reputation and career prospects. Potential ethical issues range from hardly existing to animal protection, privacy issues, and health concerns. |
| **Funding** | | |
| Citizens themselves (no external funding). | Y/N ---> % of project? | |
| Crowdfunding | Y/N ---> % of project? | |
| SMEs, their associations or organisations | Y/N ---> % of project? | |
| Large enterprises, their associations or organisations | Y/N ---> % of project? | |
| Government (agency, non-military) | Y/N ---> % of project? | |
| Military | Y/N ---> % of project? | |
| Publicly funded organisations | Y/N ---> % of project? | |
| Political parties, religious or other ideologic organisations | Y/N ---> % of project? | |
| Private persons of wealth | Y/N ---> % of project? | |
| Socio-economic enterprise/s | Y/N ---> % of project? | |
| Civil society organisation/s | Y/N ---> % of project? | |
| Philanthropic foundations | Y/N ---> % of project? | |
| European Commission | Y/N ---> % of project? | |

| | | |
|---|---|---|
| UN organisation or similar international organisation | Y/N ---> % of project? | |
| Other | Y/N ---> % of project? | |
| | | This dimension is connected to the independence of research and to (precluding) conflicts of interests. |
| **Initiators of citizen science** | | |
| Citizens with no academic education in the field | Y/N | |
| Researchers in the field or research organisations | Y/N | |
| Other | Y/N | |
| **Organisers (Who runs the project activity?)** | | |
| See groups in "funding". | | |
| | | A project can consist of several activities which are organised by different groups. |
| **Citizen scientists are known to** | | |
| Organisers | Y/N | |
| Everybody in the project | Y/N | |
| Publicly | Y/N | |
| None of them (anonymous) | Y/N | |
| Unknown issue | Y/N | |
| **Partners cooperating as citizen scientists** | | |
| Individual citizens | Y/N ---> % of project? | |
| NPOs | Y/N ---> % of project? | |
| Educational institutions | Y/N ---> % of project? | |
| Other institutions? | Y/N ---> % of project? | |
| Communities/civil initiatives | Y/N ---> % of project? | |
| **Individuals as citizen scientist(s)** | | |
| Lay persons in the field | Y/N ---> % of project? | |
| Non-academic experts in the field | Y/N ---> % of project? | |
| Sometimes also: Participants with ongoing (or partially completed) university studies in the field | Y/N ---> % of project? | |
| Users | Y/N ---> % of project? | |

| | | |
|---|---|---|
| Makers and developers | Y/N ---> % of project? | |
| School students and pupils (most of them <18 years old) | Y/N ---> % of project? | |
| **Individuals as traditional scientist(s)** | | |
| No "traditional scientists" involved | Y/N ---> % of project? | |
| Professional researchers/scientists | Y/N ---> % of project? | |
| Students in a relevant field. | Y/N ---> % of project? | |
| Persons who partly completed studies in a field relevant to the project | Y/N ---> % of project? | |
| **Topic areas and/or disciplines** | | |
| 1. Disciplinary competences in project organisation teams | Specify | |
| 2. Self-categorisation of the project by its organisers | Specify | |
| 3. Categorisation by research funders, publishers, and other researchers | Specify | |
| **Incentives and remunerations promised** | | |
| None | Y/N | |
| Symbolic (Price, worthless certificate, medals …) | Y/N | |
| Monetary remuneration | Y/N | |
| Certificate on training/experience | Y/N | |
| Recognition by naming | Y/N | |
| Other | Y/N | |
| | | In the case of monetary remuneration, the question arises, when it turns into (low) payment. A certain amount could be specified related to living costs in a country. |

### 7.2.5 Using the Activities & Dimensions Grid of Citizen Science to differentiate between the various forms of citizen science

With a view on benefits and caveats of citizen science activities, it becomes clear why it is important to differentiate: Benefits, but also caveats, to be minded depend on specific activities and how they are characterised by a specific setting, i.e. by multiple dimensions. However, in scientific literature the benefits of citizen science are generally claimed, often superficially. Strasser et al. (2018) mention three kinds of promises that are made about citizen sciences: "a greater democratisation of science, better scientific literacy, and new scientific breakthroughs" (p. 62). As described in Chapter 5.2, recognizable contributions to scientific research are plausible: by generating new questions (Elliott & Rosenberg, 2019; Schonfeld, 2019; Mah, 2017; Houllier et al., 2017), recognising knowledge gaps (e.g. Elliott & Rosenberg, 2019), making discoveries (e.g. Vohland et al., 2019; Walajahi, 2019), and expanding the scale of data collection and observations (e.g. Quinn, 2021; Resnik et al., 20xx; Riesch & Potter, 2014; Liebenberg et al., 2016; Irwin, 2018; Mah, 2017; Jones et al., 2013; Houlillier et al., 2017; Cohn, 2008; Danielsen et al., 2005; Tulloch et al., 2013). And there might be cost benefits for some research projects (e.g. Jones et al., 2013; Houillier et al., 2017). Also Kimura & Kinchy (2016) mention the promise that citizen science more or less inevitably expands scientific literacy, however, they are sceptical that this claim is fully justified. The promise that citizen science brings greater democratisation of science with it, often goes along with the claim that citizen science runs against elitism and traditionalism (Haklay, 2013, Nascimento et al., 2018, Kimura, 2016) and stands for openness and inclusion (Sauermann & Franzoni, 2015; Schrögel & Kolleck, 2019). And sometimes public engagement is confused with democratisation: The more public engagement, the democratisation there is (Robinson et al., 2018). Considering specific activities and their dimensions, it becomes impossible to make such assertions because one begins to see the intricacies of these activities.

For example, a possible impact of a citizen science activity on enhancing democratisation of science or society at large is most likely to be had in Area 1, which deals with influencing research policies, and also in Area 2 as far as citizens determine the research questions in a project or have a say in the project design. However, a positive impact is not given, on the contrary, deliberative regimes can advantage even further those who are already cumulatively advantaged. In these cases, one will have to ask which procedures are put in place and what concrete measures are taken to include people in a credibly democratic way. This is not an easy task. It is a different story, if citizens are volunteers who contribute free labour without having influence on decisions. As long as citizens have no more control over a project than volunteers in charity contexts, inclusion might not play such a crucial role. Depending on the extent to which unpaid work is given by individuals and their expertise, different, questions appear, e.g. about a potential exploitation of cheap labour force, the elimination of paid jobs, the appropriation of the extensive knowledge of practical experts and many more. A project conducted only in stable democracies is not the same as one under an authoritarian regime or in countries with unreliable administrations compared to industrialised countries. To avoid unintended effects of their activities, put people to risk or avoid strengthening non-egalitarian power structures, organisers of citizen science in the global south, who “fly in” from the global north, are well-advised to cooperate with local experts and experts on development cooperation.

### 7.2.6 Some categories & typologies taken into account in the Activities & Dimensions Grid of Citizen Science (ADG-CS)

| | **Bonney et al. (2009)** | **Used in the ADG-CS** |
|---|---|---|
| What is considered as citizen science? | No concrete specification found | |
| Categories/dimensions/ types/characteristics | Contributory projects | Data collection, passive participation |
| | Collaborative projects | Project development, data collection, data preparation & processing, analysis & problem solving |
| | Co-created projects | Project development, data collection, data preparation & processing, retrieval of scientific literature, experimenting, analysis & problem solving |
| | *Activities listed (p. 11)* | |
| | Choosing or defining questions for study | Determining research questions |
| | Gathering information and resources | Knowledge management |
| | Developing explanations (hypotheses) about possible *answers to research questions* | Project design |
| | Designing data collection methodologies (both *experimental and observational)* | Project design |
| | Collecting data | Data collection |
| | Analysing data | Analysis & problem solving |
| | Interpreting data and drawing conclusions | Analysis & problem solving |
| | Disseminating conclusions | No |
| | Discussing results and asking new questions | No |
| | *(Bonney et al., 2009a, p. 11)* | |

| | |
|---|---|
| Useful for empiric research in CS Track? | In this general form the models cannot be operationalised, hence they needed to be concretised. |
| Used in categories? | The general categories are broken down to concrete activities. Most of the activities named are also part of the Activities & Dimensions Grid of Citizen Science. Exceptions are "disseminating conclusions" and "discussing results", which the authors consider rather as a possible impact of research than a direct part of it. Asking new questions could be part of a follow-up project and then belong to the activity "determining research questions". |

| | **Shirk et al. (2012)** | **Used in the ADG-CS** |
|---|---|---|
| What is considered as CS? | "Intentional collaborations in which members of the public engage in the process of research to generate new science-based knowledge" | |
| Categories/dimensions/ types/characteristics | Contractual projects | Determining research questions |
| | Contributory projects | Data collection |
| | Collaborative projects | project development, data collection, data preparation & processing, analysis & problem solving |
| | Co-created projects | All activities |
| | Collegial contributions | All activities |
| Useful for empiric research in CS Track? | Two categories were introduced by Shirk et al., namely projects requested by citizens (contractual projects) without much further input and projects which are performed only by citizen scientists ("collegial contributions"). | |
| Used in categories? | Both distinctions added to Bonney et al (2009) were integrated into the ADG-CS. "Contractual projects" mirror the original science shop concept according to which citizens/NPOs request - but do not perform - research on certain issues. In the ADG-CS they are identified by doing only one activity, which is deciding on research questions. "Collegial contributions" are identifiable by the non-involvement of traditional scientists in the respective field. | |
| Additional remarks: | Shirk et al. (2012) also mention 5 dimensions: Inputs, Activities, Outputs, Outcomes, Impacts. While "activities" are an essential part of the ADG-CS, the others are not suitable for differentiating within the diversity of what is called citizen science but for the evaluation of projects. | |

| | Haklay (2013) | Used in the ADG-CS |
|---|---|---|
| What is considered as CS? | "Scientific activities in which non-professional scientists voluntarily participate in data collection: analysis and dissemination of a scientific project" (p. 106). (Adapted from Cohn 2008 und Silvertown 2009) | |
| Categories/dimensions/ types/characteristics | Crowdsourcing | Data collection, passive participation |
| | Distributed intelligence | Data preparation & processing, Analysis & problem solving |
| | Participatory science | Determining research questions, project development, data collection, |
| | Extreme citizen science | All activities |
| Useful for empiric research in CS Track? | Too unspecific, not operationalizable in this form. | |
| Used in categories? | The general categories are broken down to concrete activities. | |
| Additional remarks | At this time, Haklay considered "extreme citizen science" as on top of a hierarchy of the different forms of participation. | |

| | Haklay (2018) | Used in the ADG-CS |
|---|---|---|
| What is considered as CS? | Not indicated | |
| Categories/dimensions/ types/characteristics | Whole population | Not applicable |
| | Passively consume information about science | Not applicable |
| | Active consumption of science | Not applicable |
| | Active engagement in citizen science but to a limited degree | Data collection, (+ Intensity) |
| | Projects that require remote engagement | Location of participation |
| | Regular data collection | Data collection (+ intensity) |
| | Engaged in DIY Science | DIY or activities without traditional scientists? |

| | |
|---|---|
| Useful for empiric research in CS Track? | The usefulness for the categorisation is limited. |
| Used in categories? | The first step of the escalator applies to everybody being last four categories are broken down to concrete activities. |
| Additional remarks | Haklay presented the escalator in his blog and has refined it since then. It goes beyond citizen science by including how everybody (the whole population) is affected by science in their lives as well as how citizens consume science actively or passively. (It might be debatable though if reading scientific articles is a less active consumption than visiting a museum, e. g.) |

| | **Wiggins & Crowston (2011)** | **Used in the ADG-CS** |
|---|---|---|
| What is considered as CS? | "Citizen science is a form of research collaboration involving members of the public in scientific research projects to address real-world problems." (p. 1) | |
| Categories/dimensions/ types/characteristics | primary goal orientation | |
| | TYPOLOGY | |
| | Action | no |
| | Conservation | No |
| | Investigation | No |
| | Virtual | Dimension "location" |
| | Education | Partially, Area 4 School |
| | Not used in their typology yet: They identified several key dimensions to be discussed (p. 8 f.): | |
| | Degree of virtuality | Part of dimension "location" |
| | Project demographics | Dimension "considered as citizen scientists" |
| | Organisational affiliations | Funding/Initiators/Organisers |
| | Funding sources | Funding |
| | Multiple types of outcomes | ---> Evaluation |
| | Features of processes and technologies | Openness - barriers? |
| | Numerous specific aspects of project and task design | |

| | |
|---|---|
| Useful for empiric research in CS Track? | Their typology according to primary goal orientation is more useful for a post-evaluation of the benefits of certain activities than for a distinction between different forms of citizen science. |
| Used in categories? | Only "virtual" (dimension “location”) and "education" (Area 4) |
| Additional remarks | The primary goal orientation was not included in the ADG-CS with the exception of activities in Area 4: schools: where "education" can be identified as primary goal orientation. Firstly, if citizen science is deemed science: "investigation" should always be a goal. Secondly, a prioritisation of goals may not be present in all activities, which can be a mixture of different aims. Thirdly, different views on the primary goals by different individuals or groups are possible. Instead of using "primary goals" as a mean to distinguish between forms of citizen science, it is useful for investigating outcomes and impacts. Additionally, it should be part of post-evaluation which outcomes/impacts were intended, which were transparently communicated and which were unforeseen effects of a project. |

| | **Wiggins & Crowston (2012)** | **Used in the ADG-CS** |
|---|---|---|
| Categories/dimensions/ types/characteristics | Established 5 clusters (A - E) which show different patterns of the weight given to different goals. Below the relation between the weight of these goals is shown. | |
| | <u>Goals</u>: Science : Management : Action : Education : Conservation : Monitoring : Restoration : Outreach : Stewardship and Discovery | |
| | <u>Cluster A</u>: 0.1 : 0.09 : 0.1 : 0.1 : 0.1 : 0.11 : 0.09 : 0.1 : 0.11 : 0.09 | |
| | <u>Cluster B</u>: B: 0.17 : 0.01 : 0.01 : 0.16 : 0.09 : 0.16 : 0.01 : 0.14 : 0.11 : 0.15 | |
| | <u>Cluster C</u>: 0.13 : 0.08 : 0.09 : 0.12 : 0.1 : 0.12 : 0.05 : 0.11 : 0.09 : 0.12 | |
| | <u>Cluster D</u>: 0.16 : 0.1 : 0.1 : 0.1 : 0.12 : 0.14 : 0.06 : 0.08 : 0.12 : 0.02 | |
| | <u>Cluster E</u>: 0 : 0.21 : 0 : 0 : 0 : 0.21 : 0.21 : 0.17 : 0.21 : 0 | |

| | |
|---|---|
| Useful for empiric research in CS Track? | It confirms that goal orientation is not a clear-cut issue and categorising citizen science by goal is not practical. The goals above could be rather used to evaluate outcomes of citizen science. |
| Used in categories? | Partially (see comments on Wiggins & Crowston (2011)) |

| | **Wiggins & Crowston (2015)** | **Used in the ADG-CS** |
|---|---|---|
| Categories/dimensions/ types/characteristics | Funding | Dimension "Funding" in the ADG-CS, more detailed operationalisation. |
| | Sustainable mix | |
| | Grants & membership | |
| | Private donations | |
| | Entrepreneurial | |
| | Goals | See above. |
| | Resource management & conservation | |
| | Scientific knowledge | |
| | Education | |
| | Participation activities | Activities and disciplines/research areas are 2 different dimensions in the Activities & Dimensions Grid of Citizen Science. |
| | Natural history observation | |
| | Environmental quality monitoring | |
| | Content processing | |
| | Data quality processes | Rather evaluation issue than distinction. Data quality to be decided by review by scientific community. |
| | Observational data | |
| | Measurement data | |
| | Replication | |

| | | |
|---|---|---|
| | Communication media | Partially in dimension “location” |
| | Science & data | |
| | Basic coordination | |
| | Social networking | |
| | Rewards | Dimension “incentives” |
| | None | |
| | Competitive participation | |
| | Volunteer appreciation | |
| | Social opportunities | |
| | In person | |
| | Distributed socialisation | |
| | Formal education | Dimension “incentives” |
| Useful for empiric research in CS Track? | Among others, their multidimensional approach is mirrored in the Activities & Dimensions Grid of Citizen Science, although in a different structure. | |
| Used in categories? | Several of their dimensions/activities can be found in the Activities & Dimensions Grid of Citizen Science. | |
| Additional remarks | Wiggins and Crowston show how many dimensions citizen science activities have, since they have been developing more complex models over the years. | |

| | **Cooper et al. (2019)** | **Used in the ADG-CS** |
|---|---|---|
| What is considered as CS? | "Globally, citizen science encompasses an enormous range of activities in which millions of people contribute to research in science, technology, engineering, and mathematic (STEM) fields." (p. 1) | |
| Categories/dimensions/types/characteristics | Institutional research / human subjects / personally identifiable data | Several dimensions |
| | Institutional research / human subjects / open, if personally identifiable data | Several dimensions |

| | | |
|---|---|---|
| | Institutional research / no human subjects / no personally identifiable data | Several dimensions |
| | Institutional research / no human subjects / personally identifiable data | Several dimensions |
| | Non-institutional research / human subjects or no human subjects/ personally identifiable data or not | Several dimensions |
| Useful for empiric research in CS Track? | Cooper et al. (2019) show how with different combinations of dimensions have a have a strong impact on which ethical considerations are necessary. | |
| Used in categories? | Their model appears in the Activities & Dimensions Grid of Citizen Science by combining "Organisers (Who runs the project?)" and "Beings dealt with", where a subcategory are humans which are split into identifiable/non-identifiable. | |
| Additional remarks | Cooper et al. (2019) demonstrate that differentiation between forms of citizen science and settings in which they can takes place are more than theoretical reflections. They have or at least should have real consequences for ethical standards. | |

| | **Franzoni & Sauermann (2013)** | **Used in the ADG-CS** |
|---|---|---|
| What is considered as CS? | "While a common term for these projects has yet to be found, they are variously referred to as "crowd science", "citizen science", "networked science", or "massively-collaborative science" (Young, 2010; Nielsen, 2011; Wiggins & Crowston, 2011). Even though there is significant heterogeneity across projects, they are largely characterised by two important features: participation in a project is open to a wide base of potential contributors, and intermediate inputs such as data or problem-solving algorithms are made openly available." (p. 1) | |
| Categories/dimensions/ types/characteristics | Openness with respect to project participation | Requirements |
| | Openness with respect to intermediate inputs | No |

| | | |
|---|---|---|
| | Nature of the task outsourced to the crowd (Task complexity & task structure) | Activities (+ dimensions) |
| | Typical skill requirement: domain specific expert skills, specialised human skills, common human skills | Requirements |
| Useful for empiric research in CS Track? | Their model emphasises the importance of distinguishing between the broad range of possible involvement of participants. | |
| Used in categories? | In the Activities & Dimensions Grid of Citizen Science the complexity and structure of tasks are further specified by different dimensions that can characterise different activities: e.g. intensity, location, beings or objects dealt with. | |
| Additional remarks | They refer to the vagueness of the terms and prefer the term "crowd science" which they use synonymous to "citizen science". | |

| | **Schrögel & Kolleck (2019)** | **Used in the ADG-CS** |
|---|---|---|
| What is considered as CS? | "Inclusion of non-traditional, non-institutionalised and non-professional researchers in the process of knowledge generation, including research processes conducted without institutionalised scientists at all" (p. 81) | |
| Categories/dimensions/ types/characteristics | Dimensions of the Participatory Science Cube | |
| | Normative Focus (Public decision making, public collaboration, public consultation, public discussion) | |
| | Epistemic Focus (crowdsourcing, public input for analysis, public collaboration for interpretation, public problem definition & interpretation) | |
| | Reach (Other experts, Organized Civil Society, Interested Public, Broad Public) | |
| Useful for empiric research in CS Track? | Schrögel & Kolleck (2019) conducted a meta-analysis of several models of public engagement in science scholars, which are often referred to and developed a model that brings them together. A project is placed in their cube according to their three dimensions, which shows how multiple the facets of what is considered citizen science can be. | |

| | |
|---|---|
| Used in categories? | The multi-dimensional approach is reflected in the Activities & Dimensions Grid of Citizen Science. |
| Additional remarks | The authors adapt the democracy cube by Archon Fung to develop a 3-dimensional model, their "participatory science cube". |

| | **White paper SOCIENTIZE (2014)** | **Used in the ADG-CS** |
|---|---|---|
| What is considered as CS? | Citizen Science refers 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. (p. 8) | |
| Categories/dimensions/ types/characteristics | MODELS OF CITIZEN ENGAGEMENT IN SCIENCE | |
| | Pooling of Resources | Passive participation |
| | Serious Games | Part of analysis & problem solving |
| | Participatory Experiments | Action research or experiments? |
| | Grassroots Activities | Dimension "Organisers (Who runs the project?)" |
| | Collective Intelligence | Part of analysis & problem solving |
| | Data Collection | Data collection |
| | Analysis Tasks | Part of analysis & problem solving |
| Useful for empiric research in CS Track? | The White Paper gives a strong impression of how many facets activities can have that are considered as citizen engagement in science. | |
| Used in categories? | The models are reflected in the Activities & Dimensions Grid of Citizen Science. However, the ADG-CS does not list serious games, furthermore, the ADG-CS does not differentiate between collective intelligence and analysis tasks. | |
| Additional remarks | The names of the models seem to be highly self-explaining. Nevertheless, it has to be remarked that no detailed descriptions of the models have been found in the document, hence misinterpretation from our side cannot be precluded. | |

# 8 Conceptual models for computer analytics

*Sven Manske, Ulrich Hoppe, Nils Malzahn*

## 8.1 The role and context of computational analytics in CS Track

As many other scientific activities also citizen science and its results are nowadays to a large extent projected to digital spaces for purposes of collaboration, communication and publication. These “digital traces” can be submitted to computational data analysis, which can reveal such aspects as the roles of and relationships between actors involved, the interaction with other areas of public life and society as well as thematic trends and alliances. This is an important ingredient to CS Track’s approach to monitoring and analysing citizen science activities. The core of this work is conducted in Work Package 3. A first report on this approach is available in the form of deliverable D3.1, which assembles and documents relevant analytic methods, including techniques of social network analysis, information mining as well as visualisation techniques. These techniques will be used systematically to gain insights on different levels of granularity or scales: On the micro-level, data from internal forum interactions in citizen science projects can be used to identify roles and interaction patterns between professional scientists and volunteers. A specific question here is the "richness" of the volunteers' activities in terms of initiative and reflection. These studies are typically of case-based nature. On a meso-level, larger collections of project descriptions can be analysed together using web crawling and text mining techniques. On the highest level of aggregation, one can analyse the interactions between projects, groups of projects and other entities (such as public media) relying on Twitter data including mentions, retweets, or follower relationships. This allows for reaching out even beyond the set of projects originally collected.

We are aware that computational methods applied to digital traces have "blind spots", for instance in relation to gender distribution, individual motivation, and satisfaction. Accordingly, computational approaches of analytics have to be complemented and combined with other types of quantitative and qualitative analyses used in social studies. Accordingly, CS Track adopts a "triangulation approach" to monitoring and analysing citizen science as a social, collaborative activity. The actual synthesis of preliminary and intermediate results takes place in the context of Work Package 4. This integrated and synergetic perspective is the basis for formulating quality statements and policy recommendations for different stakeholder groups.

In this overall context, the quest for conceptual models aims at clarifying the building blocks and main targets of the different kinds of analyses. In the social science tradition, this would lead to the question of defining the unit(s) of observation and analysis. Certainly, an overarching interest lies in studying CS Track activities in terms of collaboration and community interactions. However, the primary entities that are susceptible to digital data harvesting are concrete citizen science projects, possibly also project clusters (as part of platforms or program initiatives). Once a project has been found and selected, individual actors may be identified in specific digital manifestations such as publications, forums or discussion pages. According to the ethical standards established for CS Track (see deliverables D8.1 and D8.2), we would not perform analyses aiming at the individual profiling of actors. Another extension beyond the project level would be possible through the analysis of Twitter data and cross-media analyses (Hecking et al., 2019). The objects of primary interest here are actors, content items (or "memes" - cf. Shifman, 2014) as well as their relationships and trajectories.

**Building blocks for computational representation and analytics**

From a technical point of view, the design of databases and processing schemes builds in the identification of certain types of entities, together with their attributes and relationships (Chen, 1976; Thalheim, 2013). The first prerequisite here is the mapping of a domain-specific vocabulary to entities that should be computationally represented and analysed. As for the entities, we have to clarify our language definitions regarding concepts such as "citizen science project platforms", "citizen science projects", "citizen science activities", different types of participants ("professional scientists" vs. "volunteers") and types and roles of participation in citizen science projects or activities. The current version of the CS Track database built up as part of Work Package 2 is essentially centred around projects as primary entities.

As a next step, we need features or attributes as descriptors associated with the identified basic entities. To build up a comprehensive collection we first need to focus on easily available information that does not require a high degree of subjective interpretation, analytic (semantic) processing or empirical research beyond direct observation and simple questionnaires. This kind of information is currently being gathered in the Work Package 2 database. Typical features or attributes for the primary entity of type "project" would be <project name>, <website URL>, <start date>, <location(s)>, <platform(s) on which the project is listed>, etc. The identification of (multiple) disciplines relevant for a given project is already a challenge, but I would still see it in this group of basic descriptors. Simple analysis techniques based on keyword extraction and matching against keyword lists can achieve this. Characterising activities as "online" vs. physical or "in the field" is also among the not too difficult options. This is quite easy to observe from available descriptions of projects but it is not just "binary": E.g. you may have field observations (on the part of volunteers) that are encoded, uploaded and possibly geo-mapped in an online environment. We need description categories for such situations. A more difficult point is the demographics of the participants, number, gender and age distribution etc. Although it is a basic and important descriptor it may be difficult to get access to this kind of information.

Based on projects as the primary unit of description, we can subsequently model important relations of projects with other entities. These may be abstract entities such as purposes, for instance SDGs or educational goals, come into mind immediately. Also institutions may be important here ("associations for conservation of XYZ"), as well as items taken from political agendas. The relation of different citizen science projects among each other is another potentially relevant "relational" feature. Here, analytic tools (as described in D3.1) can help by analysing micro-blogs (such as following, retweets of mentions on Twitter) or cross references between project web pages. Such analyses would involve larger sets of projects. Different in scale but still on this level of distance from basic observations is the analysis and characterisation of roles, discourse and working relations inside projects. These analyses are confined to a smaller sample of projects and need substantial effort for each single case.

The highest degree of processing and interpretation, i.e. the largest distance from basic observations, would be related to (comparative) quality judgements, identification of deficits and societal benefits. The mapping to MoRRI indicators would be part of this kind of work. In CS Track, this work is mainly allocated in Work Package 4 as a later step in the synergetic triangulation process.

**Specific methods**

The actual computational methods adopted within CS Track are described in D3.1. One group of methods belongs to the field of Social Network Analysis or SNA (Wasserman & Faust, 1994; Borgatti et al., 2009). Network analysis techniques are means to study the impact and inter-connection of projects in terms of information exchange through web-based and other media ("information diffusion", cf. Hecking et al., 2019). If we see projects/initiatives as nodes in a network linked through information exchange and ensuing communication relations (inter-linking of websites, mentions of Y on pages created by X, Twitter connections through retweets of follower relationships etc.), we can apply network-based measures of relevance in terms of different types of centrality and we can identify certain levels of cohesion or inter-connectedness in larger group of projects. This gives us measures of "influence" that can be interpreted as indicators of impact or success.

A second group of methods aims at analysing content from a semantic point of view. The prevalent type of content in this line of analysis is text. Textual data can be retrieved from the public pages of projects or platforms from the world-wide web or social media. Technically, it is also possible to analyse videos relying on automatic voice-to-text transcription for pre-processing. The primary outcome of these content is a characterisation of the given object of study (e.g. a citizen science project) in terms of topics or themes. Specific methods also allow the extraction of relational structures in the form of semantic networks or concept maps. "Epistemic Network Analysis" (ENA, cf. Shaffer et al., 2016) combines the extraction of semantic networks with a statistical analysis that allows for characterising the importance of certain topics in comparison between different example texts. Also newly emerging relationships and topics may be considered as an indicator of recent trends, which in turn can guide the revising and adaptation of science curricula in the light of new developments.

Other more general techniques of web analytics such as web crawling and basic statistics can already provide survey information. These combine well with information visualisation techniques to display statistical findings, render networks or to present data in a geo-mapping context.

Regarding the added value and benefits originating from web analytics, we would particularly mention the following targets:

- Automatic extraction of basic information from project web pages using basic techniques such as named entity recognition, keyword extraction in combination with crawling and scraping of web pages;
- Assessment of key research areas as well as type of scientific discourse using semantic methods of analysis such as ESA ("Explicit Semantic Analysis") or ENA;
- Detection of connection and inter-relations between different citizen science projects and possibly public media based and Twitter and other social media channels;
- Assessment of public visibility of citizen science activities and projects in digital media.

# 9 Some open research questions

*Michael Strähle & Christine Urban*

During the work on this report, it became apparent that many questions remain unanswered regarding citizen science due to the lack of empirical evidence. In order to stimulate further research, the authors list below questions that they consider urgent to answer in order to gain a basis for policy decisions on citizen science based on sufficient empirical evidence.

These questions were formulated against the background of the expertise available in the consortium in humanities, social and computer sciences. This is not a final list of open research questions; the next report (D1.2) will contain additional ones.

As already noted, the scientific literature on citizen science consists largely of case studies and project presentations; cross-project comparative analyses are rare. Such analyses are a desideratum. For instance, a secondary analysis of case studies and (self-)presentations of citizen science activities could be performed. Were the authors involved in these activities? Which case studies represent (self-)reflection and to what extent?

Generally, in research on citizen science only some geographic areas are covered. Compared to research on citizen science in the English- and German-speaking area, there is only little research on citizen science in Africa, Asia, Latin America and also many European countries, especially the Slav regions.

**Terminology questions**

- It seems that some prominent terms and concepts used to describe citizen science are only used by certain actors. Who uses the following terms and concepts: citizen science, open science, participation in research, public engagement in science, participatory research, and similar expressions, how and in which contexts? What other terms, concepts and attributes are used to describe citizen science?
- In what contexts and publications - e.g. scientific literature, policy papers, and social media - do terms and phrases such as co-creation, co-production, co-design, extreme citizen science appear? Who uses them?
- Who says they do citizen science? How do lay person use the term “citizen science”? Are there differences in terms of terminology how professional scientists organising citizen science activities and lay persons participating in them describe what they do?
- What do lay participants in citizen science think about the term “citizen science”? To what attributes for citizen scientists do they agree?
- Should the term "citizen science" be kept at all and if yes, for which forms of citizen science?

- What definitions and explanations of citizen science do policy makers and citizen science projects, associations, platforms and funders present? If they refer to sources, what are they?)
- Who claims to define citizen science? And who actually defines it?

**Participation issues**

- When is the frequency of contributions by individual participants (upload of photos, etc.) increasing? When the frequency is decreasing or contributions stop abruptly, are reasons given for it by participants?
- Can withdrawal patterns be detected? Are they connected with requirements or restrictions for participation, such as technical requirements? For instance, because smartphones, cameras, tablets, etc. citizen scientists use, have become outdated.
- Retention issues: Why do participants drop out of citizen science activities? If some barriers can be identified, removing or mitigating them, they would become possible "enablers".
- Who is actually involved in citizen science activities? What characterises these participants?
- Who are the "citizens"? Shall we call citizen scientists depending on industry sponsorship citizen scientists?
- Image analyses: In what roles are different participants presented in images? What people are visible on images? (=Image analyses: In what roles are different participants presented in images? Which people are visible on images?)

**Integrity and transparency issues**

- Transparency of citizen science projects: What means (website, etc.) do project organisers use to disclose information about projects? And what information is given?
- Are there differences and contradictions between the objectives and use of the results as they are presented to citizen scientists and those indicated in academic presentations?
- Are there differences between the self-presentation of a project and how it is described by project coordinators, citizen scientists, other researchers and other actors?
- How can citizen science safeguard itself against instrumentalisation?
- Which forms of citizen science with which characteristics should be safeguarded against which risks and misconduct?
- When it comes to decision-making in research, when is it desirable and when is it not desirable that "citizens" should be involved? When would it give concerned groups a voice, when would it allow powerful groups to influence research? In what kind of citizen science activities and under what conditions?
- What research activities should not be tackled by citizen science? Can ethical conduct be ensured to a necessary degree for all involved people, if they do not risk their professional reputation?

- What citizen science can be considered Responsible Research & Innovation (RRI) and in which respect? What are their characteristics?
- What is the dark side of what kinds of citizen science? (non-intended adverse effects, limitations, deficit models, opacity)

**Educational issues**

- Evaluation of citizen science as a teaching method: How does it compare to other teaching methods?
- Citizen science in schools: To what extent is citizen science an appropriate didactic tool for weaker, disadvantaged pupils or those from families less inclined to education or with little education? For this question one could ask teachers and parents what advantages and disadvantages they see in using citizen science in the classroom. For what reasons do they embrace/reject or (not) consider citizen science for teaching?
- To what extent is citizen science suitable for science education on subjects that are less often favoured by pupils, such as STEM subjects like physics and chemistry?

**Other questions**

- Several claims are made about the benefits of citizen science. Which citizen science activities have which benefits? What are the characteristics of these activities? What are the necessary conditions and requirements for bringing about these benefits?

# 10 Concluding remarks

*Michael Strähle & Christine Urban*

To provide a framework for the research to be conducted in Work Packages 2-4, the research reported in this deliverable has investigated various conceptualisations of citizen science and issues of actual, potential and claimed benefits brought by citizen science for science, ethical and integrity issues, caveats and potential pitfalls. Issues of participation in citizen science that are discussed in this report include participation patterns, demographic and gender aspects, and barriers, enablers, incentives and disincentives for scientists and volunteers participating in citizen science. The chapter on education and citizen science discusses aspects of informal and formal, school and after-school, and online education. Furthermore, the visibility of citizen science activities and economic aspects of citizen science such as potential cost benefits, as they are presented in scientific literature, are assessed.

Information presented in this report is based on critical analysis of scientific literature. Although publications on citizen science activities and citizen science in general go into thousands, empirical evidence on benefits for science and society at large, caveats and pitfalls, educational, ethical, gender and economic aspects, barriers, incentives, disincentives and enablers for citizen science, and on who actually voluntarily participates in citizen science activities can mostly be found in project owners' reports about their citizen science activities and in case studies. Systematic and comparative analyses about these issues are very rare and limited to specific thematic areas. (A similar remark could be made about investigations of public engagement in science.) The empirical evidence available does not allow for generalisations in respect to the aforementioned topics. The authors therefore had to restrict themselves to exemplary presentations.

D1.1 contains a grid of important dimensions to differentiate between citizen science activities, the Activities & Dimensions Grid of Citizen Science, which was developed as a kind of checklist that builds upon the explanation of citizen science in the Science with and for Society Work Programme 2018 - 2020 and is tailored to research activities in the aforementioned work packages. The chapter on conceptual models for computer analytics describes the role and context of computational analytics in CS Track, building blocks for computational representation and analytics, and the specific methods to be applied in Work Package 3.

Among other things, the report following this deliverable discusses policy aspects of citizen science and perspectives of policy makers on it. Furthermore, it extends and refines the different identified variables into actionable rubrics for the analytics tools and highlights issues for future research on citizen science.

# 11 Note on contributions

Michael Strähle, Christine Urban and Kathy Kikis-Papadakis are editors of this report. Kathy edited 4.3 and 4.4, Christine and Michael the other chapters they did not contribute to. Contributors to this report are indicated under the headings of chapters (except Chapters 10 and 11).

Christine Urban and Michael Strähle developed a report structure which was adapted according to feedback by the contributors. At the beginning of working on this deliverable, Christine and Michael sent contributors their results of information retrieval in Scopus, which contributors supplemented with the results of their own information retrieval. Authors' names to their contributions are indicated alphabetically.

4.4.3 Julia Lorke: contextualisation, literature search, search for suitable project examples, synopsis of the findings and the writing of the subchapter

4.5 Sven Manske and Julia Lorke both contributed almost equally to the contextualisation, literature search, search for suitable project examples, synopsis of the findings and the writing of the subchapter

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