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ECSA's characteristics of citizen science: explanation notes

An articulation of the characteristics of citizen science can assist different stakeholders in identifying which activities should be considered as citizen science. Examples of stakeholders are national citizen science platforms (e.g. Heigl et al. 2018), projects (e.g. the EU-Citizen.Science project), organisations that are supporting citizen science activities (to assess which activities they should support), and funders (to agree what type of projects should be funded). Understanding the common characteristics is also necessary for those who are developing and implementing citizen science activities, and especially those who are new to the field.

Throughout the rapid growth of citizen science over the past two decades, the complexity of terminology is well acknowledged (see Eitzel et al. 2017), and therefore it is clear that agreeing on a single criterion or definition for citizen science is impossible (e.g. Auerbach et al. 2019). Yet a grouping of good practices in citizen science, which form the basis for ECSA's 10 Principles of Citizen Science, is too vague for the needs of the above stakeholders.

It is possible to demonstrate the diversity of the terminology through examples: there is little doubt that a project with an open call to a wide range of volunteers to take part in either data collection or data analysis of a clearly defined research hypothesis will be recognised as citizen science. However, this is only one type within a large set of activities, practices and forms of participation, resulting in diverging views about what is – and is not – citizen science. Because of these differences in disciplinary and cultural contexts, attempting to define a universal set of rules for exclusion or inclusion is difficult, and might even limit the advancement of the field by excluding novel forms of innovation, or fields of research that are not well represented in citizen science.

To address this challenge, the European Citizen Science Association (ECSA) and the partners in the EU-Citizen.Science project set up a working group to develop a set of characteristics of citizen science that address the areas of ambiguity in the field, and explain the range of activities that can or cannot be included within a collection of citizen science activities. The intention was to create an inclusive collection of characteristics, which will allow different stakeholders to choose which of these are the most relevant to their particular context and needs and therefore use them as a basis for criteria. For example, it is expected that a non-governmental organisation (NGO) with a focus on environmental monitoring will have different requirements from citizen science than a national medical research funding body with a remit to focus on reproducible, cutting-edge research.

The characteristics were developed by identifying areas where ambiguity about the classification of a project might exist. These were grouped into ten factors (such as activeness, compensation, data sharing), and over 60 sub-factors that can be associated with an activity. To assess the degree

to which these factors influence the understanding of what is or isn't citizen science, a vignette study was set up with 50 examples of research activities that have some involvement of the public in one form or another. These examples were based on the literature on citizen science and public engagement in science, with some created specifically for this study. Of the 50, five were selected to represent citizen science activities for which there is consensus in the literature (e.g. Galaxy Zoo, which is mentioned frequently in the literature) and five to represent activities that are frequently mentioned as excluded (e.g. a one-way public consultation). The rest of the cases were based on the different sub-factors to provide a range of examples of potential public involvement in research.

These examples were used for a survey in December 2019, to which over 330 people responded. The people who responded came from both the research community and outside, including people who identified themselves as citizen scientists. We (the working group) reached people who have long experience in citizen science and people who are new to the field. Analysis of the survey showed a good representation and coverage of views.

With an average of over 100 responses per vignette, the survey provided an indication for the variations in interpretation of citizen science. Each case yielded a significant amount of qualitative comments that assisted in the interpretation of the responses. The characteristics were developed to address and represent the totality of the views that were revealed through the survey.

This explanation document provides an interpretation of and explanation for the characteristics document, which was kept short to make it useful to different stakeholders. In this document, the characteristics document is represented, with the original text in blue and an explanation in black.

Introduction

This section is set to introduce the aim of the characteristics and some of the core issues that they address.

Citizen science is a common name for a wide range of activities and practices. It is possible to understand it by considering the characteristics of those activities and practices, which are described in this document. These are found in different scientific disciplines – from the natural sciences to the social sciences and the humanities – and within each discipline, the interpretation of citizen science can be slightly different. Yet despite these differences, citizen science is an emerging area of research and practice, with evolving standards on which different stakeholders are developing methodologies, theories and techniques. It is, therefore, useful to establish some level of shared understanding, across disciplines and practices, as to what to expect from an activity or a project that is set out to be a citizen science one.

The aim is to alert the reader to the wide range of disciplines and practices that may be part of citizen science, and to emphasise the inclusive approach of the characteristics, while also noting

that as citizen science grows as an interdisciplinary field of knowledge in its own right, it can provide insights and guidance on how to consider which type of activities fall within its remit. It is significant that the social sciences and humanities are mentioned from the outset, to ensure that all fields of research are included.

It is also important to note in the last sentence that the aim is to provide a shared understanding of activities that are defining themselves as citizen science, for example on a project's website. We should acknowledge that many activities will use terminology to describe themselves that is based on deep disciplinary roots or context-specific reasons (such as community-based monitoring, community science or participatory action research) while identifying the activity as suitable for being part of the citizen science family of activities. The decisions on how many characteristics should be included in the project in order to classify it as citizen science are open to interpretation, and the characteristics are set to assist this interpretation.

There is little doubt that a project with an open call to a wide range of volunteers to take part in either data collection or data analysis of a clearly defined research hypothesis will be recognised as citizen science. However, this is only one type within a large set of activities, practices and forms of participation, resulting in diverging views about what is – and isn't – citizen science. Because of these differences in disciplinary and cultural contexts, attempting to define a universal set of rules for exclusion or inclusion is difficult, and might even limit the advancement of the field.

The first sentence describes the project that received the clearest endorsement as a citizen science activity during the groundwork survey by people from all backgrounds and experiences, concluding that this is likely as close as possible for a universally agreed upon description among researchers, practitioners and public knowledge. Data collection and/or data analysis are the common features of the cases that were recognised in the vignettes and which received strong recognition as citizen science. Participation in other stages of the research process – for example setting the question without participation in other stages – were not recognised as strongly.

The survey reveals that beyond a very small group of cases in which a clear consensus is possible, there is much differentiation in views on most cases (including cases that have been selected as non-citizen science). Therefore, the rest of the paragraph emphasises the need for plurality. It also points to cultural differences, which are particularly important in the European context that includes very different approaches to science and public engagement. In the final sentence, we point to the risk of a rigid set of rules, and the risk of an overly exclusionary definition of citizen science that will discourage innovations. At the same time, a definition that is too fluid and open, such as the ECSA 10 principles, is not clear enough to be useful. We therefore attempt to walk the fine line between being too restrictive and too open.

Instead, this document attempts to represent a wide range of opinions in an inclusive way, to allow for different types of projects and programmes, where context-specific criteria can be set. The characteristics outlined below are based on views expressed by researchers, practitioners, public

officials, and the wider public. Our aim is to identify the characteristics that should be considered when setting such criteria (e.g. a funding scheme) and we call upon readers to determine which subset of these characteristics is relevant to their own specific context and aims.

This paragraph explains the intended use of this document and alerts the reader to the source of the views that were used as the basis. There is an explicit call to potential users of the document to consider how the characteristics fit their specific circumstances. It also points to the general approach of all the statements, which are trying to be 'inclusive' in the sense that they are respectful to different views and opinions about citizen science, which will allow different people to select which collection of characteristics is right for them. For example, we do not aim to state that a certain level of cognitive engagement is necessary, but to allow different views on how much of it is necessary.

These characteristics build on (and refer to) the ECSA 10 principles of citizen science (the 10 principles) as a summary of best practice – and projects are expected to engage meaningfully with them. Where it is especially pertinent, we refer to them in the characteristics below.

This paragraph aims to clarify the relationships between the characteristics and the 10 principles. ECSA's 10 principles have become a core reference in the field of citizen science, and they were originally created to capture the best practice principles. They cover the commitments between project organisers and participants, relationship to open science, handling of data, publications and so on. The characteristics document builds on the principles in different parts, for example in the leadership and participation section, as well as the data and knowledge section, while at the same time recognising the need for improvement of the 10 principles. The characteristics document is not aimed to replace the 10 principles, but rather to provide concrete demonstrations of some of the principles, and refer to them in different cases where a set of best practices is required; for example, if the project is built on massive passive participation, one might need to demonstrate how it refers to the 10 principles. We therefore suggest that the two documents are used together.

The rest of the document covers the characteristics of citizen science under five sections: core concepts; disciplinary aspects; leadership and participation; financial aspects; data and knowledge. Further explanation and background are provided in the 'ECSA's characteristics of citizen science: explanation notes' document. Note that we use the terms 'scientific research' and 'research' interchangeably, and we explain these terms from the perspective of citizen science practices.

The final paragraph signposts the sections of the characteristics document and points to the semantic need for blurring 'scientific research' and 'research' as terms that describe the goals of citizen science activities. This is especially critical in projects that engage the public in knowledge production in the arts, humanities, and new forms of collaboration in the sciences. Engineering research and projects that involve the monitoring of environmental or health conditions over time are also forms of research, as explained below. Without this semantic note, there is a risk of

excluding public participation in research projects that have all the hallmarks of citizen science (e.g. public digitisation projects in digital humanities) and reduce the likelihood of knowledge- and practice-sharing in projects that are actually very similar. Note that the explicit differentiation between science and research in the next section is not focused on the semantics of the document, but on the conceptual differences (epistemological and ontological) between scientific and research projects in the arts and humanities in particular. There is a second emphasis on the semantic issue in light of this wider philosophical insight.

The five areas into which the characteristics fall are as follows.

- **Core concepts.** Here, we look at the conceptual issues that might help to decide the degree of citizen science of a given project. This can be especially challenging in areas that were identified as ambiguous, such as the difference between a clinical study of digital health tools and participatory sensing activities of the exact same tools.
- **Disciplinary aspects.** Our study of views demonstrated that some areas of research are especially prone to ambiguity, or two specific issues that relate to practices within the sub-disciplines in these areas. We therefore explain what the specific issues are for each area.
- **Leadership and participation.** In this section, we focus on who is the 'project owner': the body, group or individual that has control over the project's development. We discuss the roles of participants and their engagement with the project.
- **Financial aspects.** Unlike other contributions that are happening in citizen science (e.g. time, use of physical resources, use of knowledge and expertise), financial transactions stand out as an area that can lead to contention about the classification of a project.
- **Data and knowledge.** The final section looks at how data- and knowledge-generation issues influence a given activity.

As noted, all the characteristics emerged from the study of views across a wide spectrum of background and skills, and each is recognised as a topic on which people might need guidance.

1. Core concepts

Science and research. *Citizen science practices cross-disciplinary boundaries: some belong to fields widely acknowledged as scientific research, while others fall under the general term 'research', especially in the arts and humanities. Citizen science can describe many of these activities, especially when they comply with the 10 principles. We use 'scientific research' to refer to research in the sciences, the social sciences, the humanities and the arts.*

The first point, which is linked to the end of the introduction, is the emphasis that because citizen science activities work across all areas of research and knowledge production, a strict interpretation of science will exclude many activities – such as participatory research in the arts, or digitising projects in the humanities, or in engineering – which are following all the practices and expectations of a citizen science project. While it is inappropriate to coin more terminology

('citizen research'), as this will only add to the complexities of the field (see Eitzel et al. 2017), it is critical to start the characteristics with a clarification that such practices are included. Note that while in the above we state that within the characteristics document we use 'scientific research' and 'research' interchangeably, here we are pointing to a more fundamental difference between the two: 'science' and 'research.'

What counts as scientific research? *In common with research practice in general, citizen science can address a topic that is basic or applied, inductive or deductive, local or global. In specific contexts, it is appropriate to identify a subset of activities (explicitly include environmental monitoring, or focus on hypothesis-driven research). To ensure rigour, the research should aim to follow protocols and practices in line with the disciplines within which the research is framed.*

This statement highlights that citizen science is not limited to one type of scientific or research activity, but is also relevant to applied science and to other forms of knowledge production: the hypothesis-driven deductive mode, as well as the more bottom-up inductive approach. It also can operate on different scales, from addressing a highly localised study to global issues. Within the collected views and within the literature on citizen science, there are examples of narrow definitions that are limiting citizen science only to involvement in novel knowledge that is hypothesis-driven, for example. The statement provides the scope to decide that a specific subset of research activities are expected for their use of the term. The last sentence points out that this is not a laissez-faire situation regarding the definition of research, but, instead, that attention to rigour and best practice protocols need to be considered in the design and implementation. For example, standards about careful measurements or recording of observations may need to be followed in monitoring projects.

Intention and framing. *In many fields, but particularly the medical and health sciences and the social sciences, there is a subtle difference between citizen science activities and traditional practices that view participants as subjects of research, or as participants in a survey or workshop. Therefore, the decision to call an activity citizen science should include an articulation of which aspects justify this, for example, by referencing the 10 principles.*

This statement points to one of the most complex aspects of citizen science. The range of opinions showed that in many cases, the difference between research that is not citizen science and research that is considered citizen science can only be based on the intentions and framing of the project owners. For example, the use of digital tools for data collection by a large group of people can create such ambiguity. The same action by a participant (e.g. responding to an alert from a phone and filling in details) can be part of a highly participatory project as well as a clinical study. However, in cases such as this, the burden is on the project owner to demonstrate that this is indeed a citizen science activity by indicating, for example, which of the 10 principles are applied to this case.

Hypothesis-driven research, monitoring, inductive and exploratory and scientific database creation. *Research involving citizen science can take many forms, and the roles of the participants can include, for example: identifying a research question, collecting or analysing data to support or refute a hypothesis; monitoring environmental or health conditions for management or policy outcomes; and creation of generic data within a domain to support a wide range of research questions (e.g. digitising art collections, observations or mapping). Activities can also include inductive and exploratory approaches that are based on qualitative knowledge production. In a citizen science project, it can be appropriate to focus exclusively on some of these activities (e.g. only hypothesis-driven) in specific contexts, for example when this is required by funding agencies.*

The statement points to the main methods of research that were identified as requiring clarification according to the stated views. There are, of course, further forms of research, such as inductive data-driven research. The three types above require special emphasis, mainly due to identification of the two latter types as difficult to judge, because they lack a clear scientific question that drives the participation. At the same time, alternative forms of knowledge production that involve the inclusion of lay, local and traditional knowledge or inductive knowledge creation were identified as part of citizen science. We list the different activities that participants in a project can carry out. The final sentence indicates that it is acceptable to limit the scope according to needs; as noted above, some agencies have a specific remit for funding, and therefore might focus on supporting only a specific method. This statement clarifies the 2nd principle of citizen science, that "Citizen science projects have a genuine science outcome".

Roles and responsibilities. *In citizen science, there are contexts in which it is appropriate for citizens, scientists and other project stakeholders to be considered as equal partners in the research process, and cases where the appropriate contribution is limited to data collection or providing resources. Contributors need to be aware of the act of participation, with the deliberate intention of being involved in the project. Transparency regarding the different roles and expectations in the process is recommended, and participants should be made aware that they are contributing to research. This is especially important if participants are only taking over small or micro-tasks that require little engagement, but the overall contribution to a clearly defined scientific process or research is important.*

In citizen science, there will be multiple actors: participants (citizens) and scientists, community managers, facilitators, technicians and other stakeholders. The reference to the 'research process' includes different aspects of the knowledge co-creation process, from setting the issue under investigation to the use of such knowledge. There is also recognition, in the second part of the opening sentence, that in some cases and contexts, the appropriate engagement of participants is limited to the provision of resources (e.g. computing resources), data collection or basic analysis. The recognition of these two ends of the spectrum is important to ensure that cases that are frequently described as 'crowdsourcing' – requests for micro-tasks or limited provision of resources – are included in citizen science activities. Notice that the "limited" in the sentence is

aimed at describing the situation, not to indicate that such engagement in a project is a lesser form of citizen science.

We note that participants need to be aware of the contribution and participate actively and intentionally, as this is necessary for cases where the information that participants produced is not directly used by the project, but only as a secondary use of data (e.g. reusing images that people share on a social networking site). We recommend transparency about roles and expectations, while recognising that in some cases (e.g. well-being research) the clarification of roles can impact the research design and the value of the contributions. Outside such cases, it is highly recommended to be open and transparent about choices that were made about the roles of participants. The project owner has responsibility for communicating that the participants are contributing to research. The final sentence is highlighting the importance of communication about the roles in projects that are in the area of crowdsourcing. We use "small and micro-tasks" to provide terminology that is common in general citizen science projects (small) and in crowdsourcing (micro).

Subject or participant? *In some disciplines, such as the medical and the social sciences, the shift from being a research subject to becoming an active researcher should be made clear. The nature of such studies means it is common that citizens themselves, their behaviours, challenges and health issues are under examination. But citizens can also take an active role in, and even initiate, the above activities. It is possible that the people who take part in such projects can be subjects and participants at the same time, depending on the intentions and framing of the research.*

The concepts of subject or participant are linked to both the 'Intentions and framing' and the 'Roles and responsibilities'. This emerged from the opinions that were expressed about citizen science in the social sciences, and in medical and health research. In these areas, members of the public are traditionally considered as a research subject from which the scientist extracts information and are seen as a 'data source' or 'informant' that does not take an active role in the project. The boundary between this position, and active participation in the research that will frame the activity as citizen science, is challenging to delineate. We aim to clarify the differentiation by alerting researchers to the problem of their perception and framing of the participants in the project. We also highlight that in a situation where people are asked to actively collect health information as a community researcher who is also participating in the analysis, they can be active in one part as a participant, but when analysing the data that was collected in the project that follow the practices of the discipline, they therefore see the information that they themselves provided as one of the research subjects.

Ethics. *The aims and intentions of citizen science projects and the research they involve should be communicated clearly and openly with participants and other stakeholders. If involvement is consensual and fully understood by participants, it may be considered citizen science. Special attention needs to be paid to transparency in community- or self-initiated projects that operate*

outside organisational ethical practices. In any case, all actors must adhere to a code of research integrity and quality issues when they participate in a research project.

The issue of ethics is explicitly noted in the tenth of the 10 principles, which calls for "the leaders of citizen science projects take into consideration legal and ethical issues…". The aim here is to re-emphasise the need for ethical practices, and with a linkage to the previous statements in this section. The need for communication of ethical standards "clearly and openly" is noted as explicit consent from participants. For example, cases of reuse of intentionally shared data from social media sources requires communication with the contributors, so they are aware of their contribution to research. A deliberate challenge in citizen science – that of bottom-up projects that might have different concepts of ethics and practice (e.g. self-quantification of an individual who wishes to reveal a lot of information about their daily practices) – requires special attention. The aim is to highlight that ethical considerations and informed consent are necessary for citizen science projects.

2. Disciplinary aspects

Disciplinary views. *Citizen science is applicable across all scientific disciplines, alongside a variety of disciplinary traditions and research methods. While it is well embedded within ecological, meteorological, and astronomical research, there are many areas of natural sciences and engineering that are yet to develop an approach for citizen science activities in their own area. Within these* ***scientific and technological*** *disciplines, there is a need to take into account methodological practices, standards, and conventions when designing citizen science activities.*

However, special attention must be paid in several areas. In the ***arts and humanities*** *the research approach, problem formulation and methods of data gathering and interpretation can differ from natural sciences, and it is important to acknowledge this variety. In the* ***social sciences****, participatory forms of citizens' engagement have been used extensively. For example, participatory action research and related practices make it difficult to draw a clear line between these practices and citizen science. Any research that is framed as citizen science is likely to be explicit about how it needs to be assessed as such (e.g. by using the 10 principles), and should consider how participants are moving beyond being subjects of the research.*

The opening statement is recognising that part of the complexity in understanding citizen science is in its transdisciplinary nature: it is a methodology and practice that is applied in multiple fields of research. Each of these areas of study will have its own practices, forms of knowledge production, standards for research protocols and practices, modes of knowledge sharing, and so on. While these challenges of integrating citizen science are likely to appear in every research area (be it education, chemistry or neuroscience), this section is paying attention to specific research areas where there are specific challenges, in particular in the arts and humanities, the social sciences, and medical science and human health.

In the arts and humanities, approaches that are more interpretative are commonplace. However, the growth in the digital humanities and the use of algorithmic analysis, as well as a more collaborative form of interpretation (e.g. the use of discussions and annotations tools), have blurred the boundaries between methods that were common in the natural sciences and these areas. For example, digital humanities can engage mass participation through interpretation using a common classification scheme. We therefore call for attention to the practices of research in arts and humanities, and careful consideration of how they are implemented in citizen science projects.

In the social sciences, there is a long tradition of using participatory research and developing deliberative methods in which members of the public are invited to express their views and knowledge. The practices of co-production and co-creation of knowledge are well established in some sub-disciplines (e.g. participatory development studies, public participation in urban planning). We have noted one such methodology (participatory action research, or PAR) that can and should be considered as an example of citizen science, especially if the common practices of citizen science can be demonstrated in a given project.

Yet not all participatory and deliberative approaches in the social sciences should be considered as citizen science. The common practice of research as participant observation, in which the researchers participate in a community activity, but maintain their detachment and carry out the analysis independently and without communication with members of the public, is not a citizen science activity. Deliberative methods such as citizens' juries or assemblies can be considered as citizen science if they can articulate the way in which the participants are shaping the research or performing it. This is also linked to the statement above on 'Subject or participant?', but provides a specific emphasis on the way this operates in the social sciences.

Medical sciences and human health. *Projects investigating human health (physical or mental) can present different challenges to assess as citizen science due to their varying levels of active engagement, the purpose of knowledge production, data sharing, the level of expertise required to assess medical information, and the involvement of commercial activities. In such cases, the organisational context needs to be considered: the same activity (e.g. a trial of an intervention) can be done by a hospital or a commercial actor, and therefore be assessed differently. While in other domains, sharing personal data is sometimes problematic, in the health domain it is almost a prerequisite to participation.*

Medical sciences and human health studies share with the social sciences the challenge of delineating between subjects and participants (see above). Research in these areas can mix empirical information about participants' physical conditions, which can be measured actively or passively (see 'Degree of engagement' below) with reporting and behaviour information that is provided by the individuals, especially when mental health is the topic of research. We point to the elements that require special attention, including the degree of engagement, the framing and

intention (above), and other issues that are covered in this document including data-sharing, expertise and knowledge, access and use of personal data, etc. (see the 'Data and knowledge' section). We point to the need to consider, in a context-specific way, when an activity will be identified as citizen science.

Of importance in the area of medical research and human health are the activities of the private sector in developing treatments, interventions, and carrying out experiments and product development. In many cases, a private sector actor aims, in carrying out the activities, to develop their intellectual property or establish a for-profit database (e.g. out of voluntary or paid genetic screening). In such cases, the activity will usually fall outside citizen science due to data ownership and the balance of benefits (see 'Commercial activities' above). Finally, we highlight the challenge of personal data in this area. When conducting citizen science, one should be aware of the distinction between personally identifiable data (i.e. name, birth date, address, ID#, medical records) and de-identified data, such as the ones collected in (anonymous) surveys. Notably, EU data privacy rules treat personal identified and de-identified data differently, regardless of whether it is about health or not.

3. Leadership and participation

Individual project, community-led project and researcher-led project. *Citizen science projects can be led by researchers or scientists, or can be led collaboratively by a community to address a particular issue. Projects can also be run by an individual, who will carry out the whole project alone. All are potentially consistent with citizen science, and the decision on each project can be made by examining its context and practices.*

The opening statements addressed three forms of project leadership and project ownership in terms of the person or group that are acting in this role. While researcher-led projects are commonly accepted as citizen science projects, we refer here to researchers as: scientists or engineers who are working in a research organisation; public sector environmental managers who are responsible for a local monitoring programme; and staff at an NGO who are running a project. The individual project can include a Do-It-Yourself biology enthusiast who is carrying out a project in a local hackerspace, or an amateur naturalist who is studying a specific taxon (type or group of species) in a place-based study. Community-led projects can address issues that concern a community of place which is concerned with a local issue such as a polluting facility or a community of interest, such as a group of parents who want to find out the impacts of certain health practices, and similar projects that are initiated and run by a group of people collaboratively. Notice that in such cases, we mention "led collaboratively by a community" as in some cases, there isn't a single person who acts as a leader.

Research-performing organisations, public bodies and institutions, non-governmental organisations. *Citizen science initiatives can be supported and run by different types of organisations. While commercial activities need special attention, activities that are run by public*

bodies (e.g. environmental monitoring) and non-governmental organisations (e.g. health charities) could be part of citizen science, and it is not mandatory to include professional scientists or research-performing organisations.

The second statement is addressing the organisational context in which the project is run, while the first statement focused on the project's owner. Here, the emphasis is on the different organisations that can initiate, develop and manage citizen science projects. Research-performing organisations (RPOs) – universities, public and private research laboratories – or scientific institutions are part of a wider group, and types of organisations that can host and run citizen science activities. Public bodies, such as environmental protection agencies or environmental management bodies (e.g. national parks) are running citizen science activities both within the monitoring and the research areas. Educational and cultural institutes also play a vital role, with natural history museums, science museums and science centres innovating and leading this area. Other cultural organisations, such as art museums, cultural and community centres, public libraries and schools also have an opportunity to use citizen science for novel activities.

NGOs have been identified as especially important in carrying out long-term activities and reaching out to new audiences. NGOs can use citizen science that is aligned with their mission to drive their activities and transform knowledge into action. There is potential for citizen science in the growing data-driven civic action movement, too. We also note the special need to consider the role of private-sector commercial actors (see next statement). The final sentence points out that the role of professional scientists and RPOs is not a mandatory part of citizen science, in order to explicitly allow the other types of institution to be part of the community or organisations that run citizen science projects.

Commercial activities. *If a direct commercial benefit is the main aim of an activity, and results from the use of data, for example via paid data services for the sole personal benefit of the person who shares the data and further commercial use beyond services for the data provider, it is generally not considered as citizen science. This also applies if motives for activities are perceived solely to support a marketing or business strategy, rather than supporting a unique research goal and a justified involvement of citizens. However, commercial activities that are in line with the 10 principles and are transparent could still be considered as citizen science.*

The analysis of opinions in the survey, and evidence from the wider views expressed about open science, raise special concerns regarding commercial activities and the role of private-sector organisations in initiating, running and managing citizen science activities. Nowadays, commercial activities may use activities of data-collection using sensing and scientific methods, for example in fitness apps, health-monitoring devices, or analysis of DNA for genealogy. If the only benefits for the client are in the provision of limited information only to them, while the commercial actor benefits from access to the aggregated data and may be reselling it or using it internally for the

development of future products but without opening up the data, this is not a citizen science activity.

The second sentence deals with citizen science-like activities, where the language of participation and engagement is used, but the only purpose of such activities is to support marketing or business development (e.g. a rapid increase in product adoption, or carrying out a science-like expedition without any explicit scientific outputs). Importantly, differentiation needs to be made between an activity that is aimed at private profit, and a public body that is aimed at promoting economic and social activities (such as Research Technology Organisations, or RTOs), which need to be considered as more similar to RPOs, while ensuring that the benefits of the citizen science activity produce societal goods. Despite these negative statements, the final sentence indicates that while the bar for commercial actors is higher, by demonstrating that the activities are in line with the 10 principles and other good practices, as well as transparency about the organisation goals, such organisations can run citizen science activities. This is an area that requires careful and nuanced discussion and consideration, so as not to exclude future developments and innovation.

Degree of engagement. *Active engagement that requires citizens' cognitive attention during participation in the research process is favoured over limited interaction. It is also preferable to engage citizens in several phases of the research process. Minimal participation, for example volunteers sharing computing resources or social media habits without actively engaging in the research itself, or downloading an app that automatically collects data for scientific purposes, could still be considered as citizen science under certain conditions. Examples include when a project actively aligns with the 10 principles, or supports the production of scientific results that would not have been possible without the informed decision of volunteers to contribute.*

Citizen science activities include different levels of actions by participants. The opinions that were expressed showed a significant weight being put on cognitive attention during participation. An example of projects that are considered to include limited cognitive attention is those that are focused on the use of computing resources on volunteers' devices ('volunteer computing'). In every project, there is the potential for offering higher attention, and the general view is that higher cognitive attention should be favoured. Cognitive engagement can include participation in forums, and involvement in social media activities about the project, which can also help recruitment and retention. Higher engagement can include involvement in all stages of the project, including early stages of the design or participation in analysis and the publication of outputs. The second sentence also highlights that, where appropriate, participants should be able, if they choose, to participate in multiple stages of the knowledge co-creation process. The last part of the statement provides the conditions under which minimal engagement can be considered as citizen science. As with the previous statement, the bar is set high by requiring the project owner to demonstrate that this is a citizen science project through referencing the 10 principles and similar practices.

Small scale vs large scale. *Citizen science projects can include a single person carrying out a research project and publicly sharing their knowledge on a non-traditional platform (e.g. a blog) while adhering to scientific standards (e.g. peer review). It can also consist of a small group of participants, or be open to large-scale participation in various phases of the research process. Projects may aim to achieve large-scale participation, or to contribute significantly to knowledge through personal effort, depending on the context and the discipline. Depending on the aim of the project, all scales could be considered as citizen science.*

This statement refers to the scale of activities, in terms of the number of participants. The opinions expressed about citizen science demonstrated a range of views on the number of participants that are expected in a project, including a position that assumed that citizen science needs to be a group activity. The opening sentence is addressing the inclusion of projects in which a single citizen scientist is addressing research on their own. These projects are noted in the statement 'Individual project, community-led project and researcher-led project' and can include projects that are about nature observation, medical and health research ('self-quantification') or DIY science, as well as research in the social sciences and humanities, such as investigating local history. We emphasise that as long as the research follows common research standards and practices, the publication of the results may be in a non-traditional outlet such as a blog. In some cases, such citizen scientists will publish academic papers, or share their data, though we point out that this is not a mandatory part of an activity.

The next sentences discuss larger scales: from a small group of participants, which is common in local community science projects, to a very large group of people that can be measured in the millions. The final sentence summarises the statement and provides the ability to adapt the expectations of the scale of participation to the context of the project, or the criteria that is suitable to the goals of the organisation that is setting them. For example, if the aim is to raise awareness through data collection and analysis, a large scale of hundreds of thousands of participants can be used.

Professionalism vs volunteerism. *When citizen science is understood as a collaboration between professional and volunteer scientists, the question arises: what is 'professional' and what is 'voluntary'? The interpretation of these terms varies widely and depends on context, culture and the field of enquiry. It includes aspects like professional skill sets, remuneration and timescales of involvement. For example, volunteers with a scientific background or professional scientific role in other capacities can still be volunteers when they apply their skills in their free time. They can engage in scientific activities full time and still be understood as volunteers under certain conditions (e.g. when the effort is beyond their roles).*

Some of the definitions of citizen science assume that the participants are lay people without any prior knowledge in the research area of the project. Yet both the body of research on existing citizen science projects, and the particular needs of certain activities in existing projects, show that

in some cases, the line between the professional (commonly defined as someone who is paid for an activity and frequently accredited and credentialed) and volunteer participants is blurred. The German GEWISS definition can be helpful, as it identifies professionals involved in a project as someone employed by an RPO for the purpose of the project. For example, a professional biology teacher may be a volunteer in ecological observations, or a history archivist may lead a local history group outside their work duties. The opening sentence highlights this tension and the need to consider the context and practice within the field of research.

It also recognises that some activities rely on professional knowledge, which can be central to the ability to scale up the activities. For example, information technology (IT) experts can have an important role in supporting other people within a volunteer computing project, and the statement includes attention to the scientific education of volunteers. The final sentence highlights that even when the project is in the same area as the day-to-day professional activity, if the context is that of volunteering or outside the expectation from the professional, the activity can be understood as citizen science. Therefore, the inclusion of an effort to recruit professionals should be considered within the context and aims of the project. The decision about the degree to which a science (or research) volunteering activity is considered as citizen science is linked to the 'Intention and framing' statement and requires a consideration of the role of participants in the project.

Science engagement and science education. *Citizen science projects can have educational outcomes for participants involved in various phases of the research process. Intended learning outcomes for participants are a favourable aspect in citizen science. However, for a project to be classified as citizen science, educational goals or science engagement/outreach should not be the only focus, to ensure they are aligned with the research goals. Hence, achieving higher awareness of and engagement with scientific processes can be one aim (intentional or unintentional) of citizen science projects – but should not be the main aim.*

Science engagement and a focus on education are necessary in consideration of citizen science and are an integral part of good project design. Yet some activities that are citizen science-like do not have any link to wider research efforts, and their outputs are not used in any way. Examples include a class-based scientific experiment that has the sole purpose of training students in the scientific process, or an activity in an RPO that is aimed at outreach but does not contribute to the research activity in the organisation. It is the latter type of activities that this statement is aimed at, to differentiate between the education and learning that is part of citizen science, and an education/outreach-only project, which is not.

The first sentence recognises that educational outcomes at different stages of the research are frequently an important part of citizen science projects. For example, there can be learning about background literature searches at an early stage, or statistical skills at the analysis stage. These outcomes are noted as a benefit for a project, in line with the statement in the third of the 10

principles, where learning is mentioned. The rest of the statement explains the boundary between an educational activity that does not match with the general characteristics of citizen science. A case where the education or outreach imperatives overshadow the scientific or research goals can be identified when there isn't attention to how the resulting outputs will be used for further research, or are likely to be discarded (also known as 'service-learning', which means learning that actively involves students in a wide range of experiences, which often benefit others and the community). The balance between higher awareness and engagement and the scientific goals can be a fine one. For example, the UK Royal Society for the Protection of Birds' (RSPB) 'Big Garden Birdwatch' project has a strong educational focus, but the data is analysed and reported as identification of trends in bird populations in the UK, and therefore should be considered as citizen science.

Links to decision-making. *Citizen science projects may include an intervention into the current state of affairs, such as local decision making. This might happen in activities that fall under banners such as participatory action research, community science, or addressing environmental injustice. Concerns over motivational bias in the project results can emerge in such cases, and it is recommended to pay attention to the implementation and documentation of the relevant disciplinary standards to demonstrate rigour.*

Citizen science can be used in cases where the participants are concerned with an issue and want to actively change the situation, be it concern over public health, medical support to a group of patients, or addressing a pollution issue. This statement addresses projects that aim to be part of such political or social activism. The first sentence explains what activism entails: the changing of the current state of affairs. Next, the commonality with PAR, community science and environmental justice projects is noted, although activism can also be linked to community-based participatory research (CBPR) and several other common terminologies. The main challenge that must be addressed by the project initiators and owners is to avoid bias that the motivation of the studies can create. As a remedy, it is suggested to pay attention to the implementation and recording (documentation) or the process, as a way to evidence the rigorousness of the process and its alignment with robust research standards and external peer review.

Also, consideration of how the evidence from citizen science is integrated into the issue at hand should follow logical and rational approaches. This may include professional scientists who have expertise in the relevant research area, but in some cases, a community peer review and documentation can provide similar evidence. Projects that are evidently biased in their methodology and do not attempt to follow scientific standards in their practices should not be considered as citizen science.

4. Financial aspects

The previous section included a discussion about the role of commercial activities in citizen science, and in leading projects. This section addresses the role of money, payment from

participants to the project, and from the project organisers to participants. The transactional nature of money and its linkage to paid work is influencing the interpretation of the activity, which is addressed in these statements.

Financial support for scientific research. *Pure financial support to a project, such as crowdfunding, subscription fees and donations, is not considered citizen science, as no participation in any phase of the scientific research takes place. Careful consideration of the consistency with citizen science should be made if the financial contribution is a prerequisite to a form of participation in the scientific research phase of the project.*

Of the views that were expressed about citizen science, the role of payment-only participation was among the few examples of wide agreement: that while provision of personal resources towards a scientific research is part of many citizen science activities, use of money in either crowdfunding, subscription fees or donations cannot be considered as participation in a project. Therefore, a project in which the only role of the public is financing the activity, without any further involvement, is not citizen science. Yet there are many situations where the provision of payment is linked to participation, for example in purchasing equipment that is provided by the project's organisers. Another example is in the provision of financial resources to the project coordinators to facilitate the maintenance of IT infrastructure, or the payment to the person who coordinates the activity. The consideration should take into account the implications for the way in which the project complies with the 10 principles, and how it can reach out to people without the ability to pay for participation (see next statement).

Payment to take part in a project. *Requesting financial contributions from citizens to participate in a project, for example, to finance data-measurement kits can be consistent with citizen science. But consideration should be made as to how this may affect social inclusion (e.g. excluding poorer participants) and bias participation.*

This statement is focusing on the cases that require payment to allow participation, with the examples provided in the previous explanation.

Incentives to participate in an activity. *Projects that incentivise participants can qualify as citizen science, but this is dependent on the context and form of relationship between project leaders and participants. Incentives could take different forms, such as small payments in crowdsourcing activities, or providing bikes to facilitate mobility in a place with high deprivation. However, the type or amount of the incentive should be taken into account before considering its consistency with citizen science. Acceptance of incentives/payments to participants in the citizen science context depends on the culture/country and the social/economic status of participants.*

Incentives or small payments are relevant in many projects. The use of such payments is highly dependent on the local context and practices, as well as careful consideration of the participants, their ability to participate, and if volunteering is a suitable form of participation. For example, in a

project that aims to collect and share local knowledge with a marginalised group in an informal settlement, it is inappropriate to expect people to be able to volunteer, and compensation for their time or efforts does not alter the aims and objectives of the project, nor does it turn the participants into research assistants.

On the other hand, a large incentive, which can amount to a significant proportion of an annual income, and for which the person is expected to carry out research on the instructions of the project leader, is more akin to being a research assistant and not a citizen scientist. Similarly, regularly remunerated community researchers who are integrated into the research team are not citizen scientists, but simply part of the research team. The use of crowdworking platforms such as Amazon Mechanical Turk is of particular importance, as these represent a place of work and income for the participants. Therefore, this is a crowdsourcing activity that is not considered as citizen science for the most part. The second sentence provides examples of incentives. The consistency of payment with citizen science practices such as the 10 principles needs to be considered carefully, and justified.

5. Data and knowledge

Data and knowledge generation. *Citizen science, scientific, academic, and policy-oriented research can include different forms of data and knowledge generation, including novel data generation, creation of new analyses, or production of new knowledge in written and other forms. The knowledge produced in such projects should aspire to disciplinary standards, such as appropriate data quality and quality assurance, the peer review of project publications and materials, or policy-relevant evidence that is fit for decision-making.*

The first statement about data and knowledge production highlights the need to recognise the different forms of knowledge generation that occur in citizen science activities. The statement highlights that knowledge generation is not only in the form of a scientific publication, but can take many forms, from data generation (e.g. the creation of datasets that can serve a multitude of analyses), new analyses, and also the form of knowledge generation that can be based on written, visual or audio forms. To avoid the situation in which any knowledge production will be classified as citizen science, an explicit link to disciplinary standards is noted – and therefore knowledge generation within a specific research and practice area, such as medical research, should follow the practices in that area. This also provides a scope to define practices such as the development of shared cultural resources (e.g. an encyclopedia) as a citizen science activity within the disciplines in which this is considered a scholarly endeavour.

Within RPOs, there will be a natural tendency to highlight traditional scholarly outputs (e.g. peer-review publications, open datasets) and citizen science activities that are performed in these frameworks are expected to follow these practices, and not to be framed as an engagement or outreach activity that is not linked to research.

Data ownership and use. *Citizen science is commonly perceived and placed within the open science domain, such as by complying with open data-sharing, open access publications, and full transparency of data ownership. There may, however, be cases in which data use is limited to certain stakeholder groups, the outcomes are not made public, or the publications generated are not open access, particularly with regards to privacy concerns. It is preferable for participants to own the data they generate, and they should be made fully aware of why, when and how it is used by others.*

The statement about data ownership is included to clarify that open data is a favourable, but not mandatory, part of citizen science. The opening sentence positions citizen science within the scope of open science and lists the implications: open data, open access and transparent data ownership. However, in recognition of specific data issues – such as privacy in medical and health research, or issues with confidentiality and anonymity in the social sciences, or a decision by participants that there are justifiable reasons to avoid sharing of data – the statement continues with a caveat. In all three aspects, the statement provides an option to change from the open science ideal.

The final statement is highlighting the need to ensure data ownership by participants and the responsibility to inform them about its use. This can include, as the 10 principles note, feedback to participants in the form of sharing the papers and outputs to which they have contributed. This issue is also linked to the 'Ethics' statement above. In some contexts, for example with a funder that is committed to open access, a solution can be found between protection of the basic data and open sharing of research results. Issues of data ownership also have legal implications, for example in the area of copyright. The consideration should include an appropriate discussion about the legal aspects of the data and the appropriate legal framework.

Data quality. *Citizen science raises questions about data quality, which can be addressed in a range of way, such as well-developed protocols, good design of the task to fit the purpose, and good participant support. Similar to research activities generally, data quality is a key aspect that warrants attention throughout the entire process of knowledge production.*

As noted in ECSA's sixth principle, "Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for". Within the characteristics, we recognise the need to pay attention to data quality, but also note that this should be recognised as an issue that exists across the spectrum of research activity – and therefore is not unique to citizen science. Yet within a given project, attention needs to be paid to the characteristics of the participants and the resulting data and insights. We recognise that questions about data quality are common, and that there is an extensive toolkit for addressing data quality through a wide range of methods, from training participants and ensuring their competency, to designing software tools so they can ensure high-quality outputs.

Local and lay knowledge-sharing and application. *Citizen involvement in producing and interpreting data gathered locally by community members, to raise local awareness and action, is a common model of citizen science. The active participation of professional scientists or researchers, and the sharing of results outside the local community, are not mandatory, as long as the project adheres to established research principles and practices.*

Citizen science can include cases where people in a locality (e.g. residents of a city in Western Europe, or an indigenous group in a forest in South America) collect and share information that is based on their lived experience and knowledge of a place. Similar issues can be identified in patient groups who are familiar with their condition over time and space. The sharing and application of such knowledge can form part of citizen science. In some community-led projects (see the 'Leadership and participation' section), the production and application of this knowledge is done without the involvement of professional scientists/researchers. As long as they follow common research standards, the participation of professional researchers is not mandatory. However, it is accepted that there will be contexts in which a professional researcher is needed.

Opportunistic vs systematic data collection. *Different scientific research projects can use and benefit from datasets with a wide variety of characteristics. For some analyses, a systematic and rigorously created dataset is necessary, while in others opportunistic or partial information is fit for purpose. Citizen science can contribute to both. The specific context, research aims and disciplinary practices of the project will determine where the activities fall on the spectrum of opportunistic to systematic data collection.*

This statement is aimed at clarifying the range of approaches for data-collection approaches, in a way that supports both systematic and persistence sampling methodologies. As with any piece of research, the need to ensure that the data is fit for purpose is the most important. Therefore, a consideration on which sampling scheme to use, and how the citizen science activity is structured to fulfil the necessary data-collection approach, is needed. The range of approaches for data collection, and the suitability of citizen science as a methodology to generate the necessary data, should be considered carefully to ensure that the effort of participants is not wasted. The statement recognises that different research projects will have different needs from their data, and these requirements, once articulated clearly, justify the inclusion or exclusion of specific data-collection schemes in each project.

The use of ***digital data-collection tools*** *in the medical and the social sciences can be seen as a social survey or as participatory data collection, and therefore part of citizen science. The intention and framing of the project, as well as adherence to the 10 principles, can help in deciding if such use is a citizen science activity.*

The opinions and views that were expressed about citizen science activities have shown a particular complexity when digital data-collection tools are being used. As noted in the 'Core concepts' section, in particular under 'Intention and framing' and 'Subject or participant?', the

way that the project is framed is critical to the decision as to whether an activity is citizen science or not. Digital tools, and especially apps on mobile phones, can be used within a research framing that sees the person who submits the data as a participant in a collaborative activity, or as a subject in an experiment. Apps used by themselves are not enough to declare the project as citizen science, one in which the participants have an agency and role in line with the 10 principles.

Sharing personal and medical data. *In the medical and the social sciences, the boundaries of citizen science and data-collection practices can be challenging. Sharing personal and medical data can be part of citizen science, but this depends on the framing and intention of the project, and on a consideration of whether those taking part are subjects of research or participants who are shaping and carrying out different stages of the project. The inclusion of practices that are in line with the 10 principles can assist in establishing this.*

The final statement is tightly linked to the statement 'Subject or participant?' in the core concepts section, while dealing with the specific issues that happen when personal data collection is central to the project. First, it is recognised that such data sharing needs to delineate the role of the participant: do they have an active role in the project, or are they a subject? The expectation is that, in a citizen science project, there is an explicit demonstration of how the activities comply with best practices such as the 10 principles. This statement is also linked to the 'Ethics' statement above, and attention should be paid to local ethics practices and guidance on personal and medical data.

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