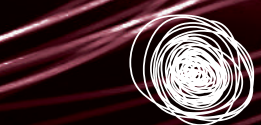
PARTICIPATORY SCIENCE TOOLKIT AGAINST POLLUTION



ACTION

Edited by Gefion Thuermer

With contributions from Neal Reeves, Ilaria Baroni, Damiano Scandolari, Mario Scrocca, Roy van Grunsven, Eddy Maddalena, Elena Simperl, Kat Austen, Franz Hölker, Sybille Schroer, Sonja Grossberndt, Dumitru Roman, Antonella Passani, Katja Firus, Rafael Gonzalez Fuentetaja, Esteban González Guardia, and Oscar Corcho

Published April 2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 824603.

TABLE OF CONTENT

RESOURCES

CITIZEN SCIENCE PROJECT CHECKLIST - THE ACTION TOOLKIT IN A NUTSHELL

This checklist, compiled by the ACTION consortium, is meant to give you a quick overview of all the aspects that need to be considered for a successful citizen science project.

Aims

- What do you hope to achieve by doing this project?

Scientific framing

- What is your research question?
- What is your research question?
- How can it be answered through citizen science?
- Have you identified any research hypotheses that you want to validate?
- Are you able to run a control experiment?

Timeline

- Over what time period do you want to carry out your project?
- What are the concrete milestones you need to achieve, and in which timeframe?
- Is there an endpoint/goal, or is it open ended?

Stakeholders

- Who is affected by and interested in the project and its outcomes?
- Who would be willing to participate?

Roles

- Who is doing what in the project?
- Are they part of the core team?
- Are they paid or engaging voluntarily, and what does this entail?
- Are there multiple ways to engage with your project depending on capacity?

Resources

- What resources do you need to implement your project, and how will you acquire them?
- What results or main tools of the project need to remain available after the end of the project, and to whom?
- What resources are needed to keep these available after the end of the project?

Reality check

- Are your expectations for your project and your citizen scientists realistic?

Ethics

- Have you considered the risks your project might pose, and how you mitigate them?
- What steps have you taken to prevent your project causing harm to your participants and environment?
- How do you account for the needs, sensitivities and expectations of the stakeholders you are planning to engage?

Data

- What data do you need to collect to answer your research question?
- Who will collect and analyse the data, and how?
- Are you collecting sensitive data (locations, names etc.), and how do you process it safely if you do?
- Where and how will you store your data?
- How can you ensure quality in your dataset?
- Where are you going to publish your data?
- What kind of licence are you going to use?
- Do you have consent from your citizen science cohort?

Communication strategy

- Have you planned your capacity for communication and dissemination?
- What will your citizen scientists and the interested public want to find out about your project?
- Do you have a central point of information that you can link to?

Community engagement

- Who is in charge?
- Who should be part of your project community?
- What methods will you use to reach out to and build the community?
- What are you doing to make your project open and welcoming for different kinds of social groups?

Sustainability

- Do you need to make the project work long term?
- How can you make sure there are enough resources to do so?

Impact

- How will you move your project from answering your research questions to effecting change?
- How will you identify and maximise your scientific, social, economic, political and environmental impacts?
- Which policy makers would be interested in the results of your project and how do you reach out to them?

WHAT IS CITIZEN SCIENCE?

Citizen science is *"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"* (European Commission, 2014). The term covers a range of activities with different levels of participation, from data collection in projects led by trained scientists to co-designing research questions and policy to science literacy and public engagement. To truly be citizen science, however, it is important that there is a scientific question and methodology, and that the activities are carried out by participating citizens. It is this citizen engagement that is inherent to the CS project and their goals.

Citizen science projects differ in many ways, such as their goals, how they organise, the technology they use, or the way they engage with citizens and other stakeholders (Schrögel & Kolleck, 2019). Throughout this toolkit, wherever possible we give diverse recommendations based on different types of projects that were represented within ACTION.

ABOUT ACTION

ACTIONParticipatory science toolkit against pollution) was a three year programme dedicated to transforming the way citizen science (CS) is conducted today: from a mostly scientist-led process to a more participatory, inclusive, citizen-led one, which acknowledges the diversity of the CS landscape and of the challenges CS teams have to meet as their projects evolve. ACTION applied a citizen science approach to tackling environmental pollution, one of the greatest threats to human health and wellbeing of our times, killing more people than smoking, hunger, natural disasters, war and infectious diseases such as HIV/AIDS and coronavirus. The research ACTION conducted accounted for the multitude of variations in CS, addressing everything from small-scale, localised social issues to international research agendas. ACTION learned about the needs of different stakeholders throughout the lifecycle of CS, and created methodologies, tools and guidelines to democratise the scientific process, allowing anyone to design and realise a CS project from the early stages of ideation to validating and publishing the results. All of ACTION's outputs are openly available. The digital infrastructure ACTION provided helps citizen scientists to use existing specialised platforms and publish results according to responsible research and innovation principles. ACTION worked with a cohort of 16 on-the-ground citizen science pilots tackling major forms of pollution. Some pilots were selected through an open call mechanism, allowing them to receive funding and support they might otherwise be unable to access. All pilots were part of the ACTION accelerator, which provided the support and guidance that the projects needed to grow and become more sustainable. The pilots in turn helped ACTION to understand different aspects of CS, co-create resources, and also act as case studies throughout this toolkit, illustrating different practices and challenges in the participatory science lifecycle. A complete list of the pilots is provided at the end of this document.

THE ACTION TOOLKIT

The ACTION toolkit is the ultimate resource collection for everyone interested in doing citizen science the ACTION way. The toolkit draws on expertise in citizen science, participatory design, social innovation, socio-economic studies, pollution, open science, social computing, open data and software development in the ACTION team, to ensure it suits the requirements of citizen science projects, addressing the practical problems that they face throughout the different stages of each project.

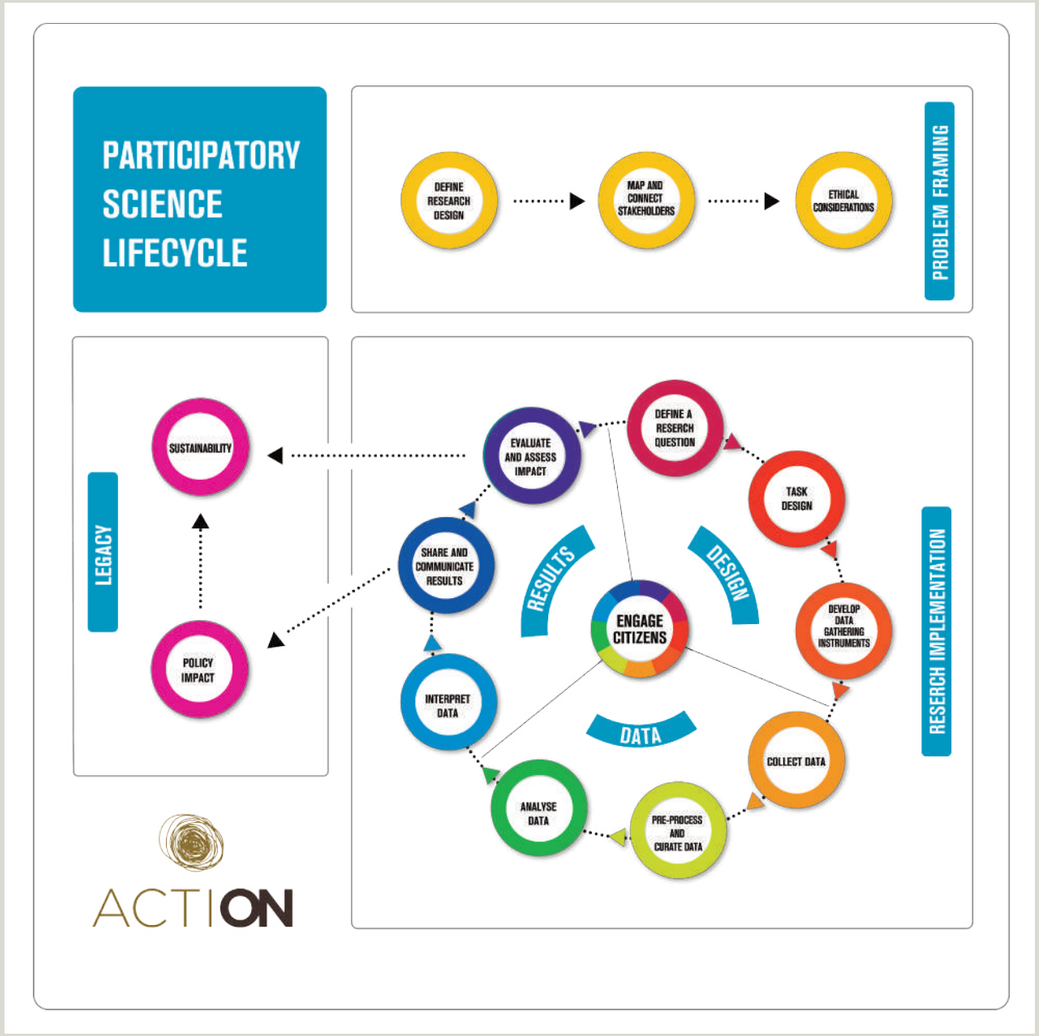


Figure 1: The Participatory Science Lifecycle

The toolkit is meant for pollution-focused citizen science projects of all kinds, and everyone who wishes to apply citizen science methods. While some of the aspects we discuss may be less relevant for non-pollution focused projects, such projects may still benefit from the insights and resources provided. The toolkit can be used by citizen volunteers, local communities interested in starting a citizen science project, researchers wishing to engage with citizens in their work, or public authorities interacting with citizens or working on policies where citizen science insights are relevant. We hope it will help them to plan, create, improve, and maximise the impact of their projects.

The toolkit follows the participatory science lifecycle. The lifecycle helps to orient your project through three stages: problem framing, research implementation, and legacy, which each include a number of steps that projects can take. The framework aims to provide guidance on what a CS project could do, and a potential order of things; it helps to break down the steps, and provides a structure that is broadly applicable to all participatory science endeavours. Both the stages and the individual steps will look different for each project, and the persons and groups involved in each of the phases may differ.

While the layout of the lifecycle may suggest a neat sequence, in practice projects will find that there are feedback loops and iterations, and that some steps will have to be taken multiple times, while others can be skipped altogether. Looking at the lifecycle as a tool in its own right will help projects understand what they have to do and consider in future, supporting their awareness and planning in earlier stages.

> The objective of the first stage, problem framing , is to define the basic project design, engage relevant stakeholders, and consider the ethics of the planned project. In this phase, the whole project lifecycle should be considered to set appropriate goals for the project and consider details such as the impact it aims to achieve and how it is to be maintained and financed.
>
> In the second stage, research implementation , the citizen science project is implemented. This encompasses three phases:
>
> > During the design phase, projects define their methodology, create tasks for participants, and select or develop appropriate data gathering instruments.
> > In the data phase, projects acquire, curate, process, and analyse their data.
> > In the results phase, projects summarise, publish and disseminate their findings for different stakeholder groups, and assess their impact on both the issues they are trying to address, and society, including their own participants.
> > Citizen engagement, while often focused in the research implementation phase, should ideally happen throughout the entire project lifecycle.

In the third stage, Legacy, projects find and use routes for policy agenda setting, help formulate policies, influence decisionmaking and the implementation of policies. They also work towards sustainability of their community and finances.
The toolkit offers an introductory overview and guidance, a selection of tools, guidelines and recommendations, and case studies for each phase and stage, to help CS projects understand and replicate best practice.
Users of the toolkit should consider which of the CS project types they are closest to, noting that it may be multiple. The typology will help them to position their project in the context of the resources and case studies we discuss. We will come back to them as we move through the participatory life cycle.
The toolkit cannot and does not want to be exhaustive. It is based on the collective experience and expertise in the ACTION accelerator, as well as the wider citizen science community. It includes tools and resources developed by ACTION and others that we have found useful in practice. We will keep adding to it beyond the lifetime of the ACTION project. You can send suggestions to info@actionproject.eu.

PROBLEM FRAMING

During problem framing, projects define and refine what they want to do, and why. They outline the problem they want to solve, narrow it down to a specific aspect they want to address, gather background information on that issue to enable their project, and create a plan for what they want to do and achieve. They also explore whom they need to engage, both as citizen scientists, and as external stakeholders. At the end of this phase, projects should have a clear plan for the research that will be carried out, and the goals they want to achieve.

Guiding questions

In defining and framing the problem, projects should consider the following questions:

- What is the issue at the heart of the project? Why should people care about it?
- Is the project timely? Has the issue been addressed before, and if so, why is now a good time to do so again?
- Who are the relevant stakeholders? Who would have an interest in this issue, and why? Who will be impacted if the project finds a solution to the problem?
- What are the geographic boundaries of the issue / the project? A problem such as air pollution can be global but be addressed locally, or on a wider scale. The intended scale has implications for the design of the project.
- What is the timeframe of the project; is there a set deadline, or will it be a continuous effort?

There's three steps to cover in this phase:

- Define the research design
- Map and connect the stakeholders
- Consider research ethics

At first glance these may give the impression of being sequential, but they are actually rather iterative: Defining the overall topic should be treated as a starting point, as everything else will flow from this initial spark. But then, gathering background information and narrowing the topic can go hand-in-hand. Background and contextual information is required in order to narrow the topic, and narrowing it down to a more specific area or question will trigger the need for more background information. On the other hand, the background may already be well-understood in the project team, and narrowing the topic may not be necessary at all, if it is already very specific from the start.

Particularly for grass-roots citizen scientists and those without scientific training, a local library can be a fantastic resource to find information on a variety of topics. You can use their local or online catalogues to find relevant books and articles, or even policy reports. Librarians will be happy to help you get started using their systems. Online platforms, such as Google Scholar or Researchgate, allow you to search for research publications in a specific area, and often provide access to the research output, or contact to the authors. Most researchers will be happy to send you a copy of their publications.

It is also useful to explore the landscape of citizen science, as well as the issue at hand. Maybe there are other citizen science projects or communities already working on a similar issue, or scientists at the local university or councillors interested in the issue already. There might be businesses or (non-governmental) organisations already addressing the problem, who could be powerful allies. The stakeholder mapping tools we provide below can help to do this.

Commonly, the framing of a problem is determined predominantly by the individuals who start a project. Grass-roots citizen science projects may be framed by citizen scientists and local residents, for example, but more established research projects tend to be framed predominantly by scientists. This is not a fixed rule, however and you should consider where your project sits, and which other stakeholders your project may appeal to.

Regardless of who starts a project, at the end of the problem framing phase everyone with an interest or influence on the topic should be involved in some form.

For example, a group of citizens may want to improve air quality in their neighbourhood. From that shared issue, they decide to take action and do something about it. With that decision made, the issue becomes a project, and the citizens will need to look into the background to the problem: How is air pollution defined, how is it measured, what does their city already do in this regard? This, in turn, will allow them to narrow their focus, such as to measure a specific type of pollutant, or to influence a policy decision by their local council. That, in turn, may lead them to investigate which sensors might be useful to deploy, or exactly how the decision they are seeking to influence is made, and what options they have to engage with councillors.

On the other hand, a project could start with a researcher who has an interest in the effects of air pollution on health. They might then decide to engage citizens to measure air quality in different locations across the country, and map this data to health issues reported in that area. A researcher will likely already have some background knowledge in their respective field, and thus will focus on the specifics of the project, such as which locations would be best, or how to motivate citizen scientists to work with them.

Regardless of the project type, at the end of the problem framing phase, the project initiator(s) should have a clear view of what they want to achieve broadly (e.g. convince policy makers to address the issue of air pollution in the neighbourhood) and specifically (e.g. collect evidence for air pollution with a number of sensors located at citizen scientists' homes for several months), and why this is important. Project goals and scope should be clearly documented before moving on to the implementation phase.

RESEARCH DESIGN

The research design begins with the definition of the project goals, and involves creating a plan for the research implementation as a whole, including data collection and analysis, and the role of participants with potentially different skill-sets at different points in the project. The research *design* is the grand picture to the focused scenarios of the research *tasks* (which we will discuss in the 'Task Design' section of this toolkit). All CS projects need to define their research questions and agree on the methodology or protocol they will follow to carry out the data collection.

Research design depends on project goals and framing, and can therefore vary across project types. Especially if the project wants their research results to be robust enough to serve as evidence for policy-makers or professional researchers, it will require a high level of expertise, which projects may have to seek externally. Sometimes the project research design may follow naturally from the project goals. In a grass-roots citizen science project focused on air pollution in a particular area, for example, a clear approach is to use sensors to measure pollution. In ACTION pilot Citicomplastic, researchers wanted to know whether bioplastic could be composted at home, so they placed composters in participants' gardens and let them try it out.

Other projects may be more complex and pose unique challenges for the question of research design. Longer projects may involve multiple stages or parallel processes of data collection and analysis which may need repeating and adapting. For example, De Vlinderstichting monitors butterfly and dragonfly populations across the Netherlands over time. To do this, they created a structure of routes (transects) at which they want to measure populations, with different schedules based on life cycles of butterflies and dragonflies. The project has been running for several decades, and in such cases it is simply not possible to delay data analysis until data collection is complete.

It is also important to consider how the research design functions in terms of scale. Large-scale research projects conducted globally or internationally need a research design that can be performed by a high number of participants in diverse locations. For example, Loss of the Night wants to understand the issue of light pollution globally, so they require measurements from all over the world, which they enable through an app anyone with a mobile phone can use. This is also true of online projects, although this can be facilitated with a platform through which data can be submitted electronically via a website or app, through social media, or text messages. For example, the Restart data workbench project developed a web application participants could use to assess reasons for faults in a variety of devices.

At the end of the research design phase, projects should know what they want to find out, what data they will need in order to do so, how they will collect this data, and how their participants will be engaged in achieving the project goals. While defining their research design and methodology, projects may want to identify and reach out to stakeholders who would benefit from the data or outputs from the project, to ensure their results will be relevant and reusable for them (Roman et al., 2020).

Tools - Assessment and Support template

What are the underlying values that motivate you to start a citizen science project? This document has been designed to help carry out a structured analysis of values by citizen science project leaders and designers. Initially working on a values matrix, this worksheet helps map these onto project objectives, and aids decision making to steer the direction of the project. This tool is developed for use within the ACTION Accelerator, but can also be used by project leaders and team members on their own.

Case study - AZOTEA

Astronomers at Complutense University of Madrid (UCM) wanted to know what impact the lockdown in March 2020 would have on light pollution in Madrid. As they were already experts in the field, and running other citizen science projects on light pollution (such as Street Spectra), they developed a framework for a citizen science project based on this question. They reached out to the local astronomy club, and brought a number of volunteer amateur astronomers on board to help them collect images of the night sky throughout the lockdown.

Case study - Noise Maps

A local community group wanted to explore the sonic heritage of their neighbourhoods in Barcelona and collect evidence for policy makers to tackle the growing noise pollution in the area, and approached the Barcelona Citizen Science Office, who put them in touch with NGO BitLab. BitLab had already worked on a similar project, and had a working relationship with experts from the Universitat Pompeu Fabra. The NGO and community members co-developed the idea of Noise Maps, which would see audio sensors installed in those neighbourhoods to collect sound samples.

STAKEHOLDERS IN CITIZEN SCIENCE

The people and organisations with an influence on or interest in the project are collectively termed the project's stakeholders. There are six main stakeholder groups in citizen science (Göbel et al., 2017):

- Academia and research organisations
- Individual volunteers
- Government agencies or departments
- Informal groups / community members
- Educational institutions
- Businesses and industry may have a stake in these projects, for example as providers of sensors or expertise, or as polluters in the area

In our example of a neighbourhood air pollution project, the citizens are the project's initiators, and they design the projects' delivery. The local council, as policy makers, may also be stakeholders because the results of the study could influence policy decisions. Other stakeholders include citizen scientists that the project initiators recruit, who may be brought on board to consult on the design of the experiment, as data gatherers or data analysers. The project may also involve open source hardware designers as stakeholders who advise on the use and distribution of sensors.

In the example of a researcher-led investigation of health effects of air pollution, the researchers - who have an existing expertise in the research area - initiate the project. They recruit citizens - who may or may not be affected by the problem that they are studying - to become citizen scientists. While definitions vary widely, in these examples citizen scientists can be considered to be those working on the project outside of their professional environment, whereas researchers are understood to be working somewhat within their professional environment. Other stakeholders could be policy makers those who engage with the project as someone able to influence policy or legislation, citizens - members of the community or members of the public who are not engaging with the project directly, and participants - those who are engaging with the project in a less active way than citizen scientists.

While professional researchers do not have to be the initiators of citizen science projects, it is recommended that projects involve a scientifically trained advisor, to ensure a genuine science outcome.

It is important to understand who the relevant stakeholders are to maximise chances of a citizen science projects' success (Skarlatidou et al., 2019). It is also important to remember that any single person can represent multiple stakeholder groups at once, by being, for example, a policy maker and a participant, and that each person and stakeholder group can fill different roles at different times in the project.

Tools - Stakeholder mapping

Stakeholder mapping is more commonly done in the context of business and innovation, but can be crucial to explore the environment and community around citizen science projects as well. Mindtools offers a template and process that can be used for citizen science projects, too.

RESEARCH ETHICS

Research should do no harm - this is true for professional science, as well as citizen science. Projects should consider what potential harm their activities could cause, to their participants, their objects of study, or their wider environment. When embarking on a project, all potential risks should be identified and assessed, and mitigation strategies developed, preferably in a formal risk assessment. While it may be tempting to dive straight into practicalities or the research topic in more depth, it is imperative for projects to consider the risks and implications of their work *before* that. Only if these ethical questions are considered from the very beginning can the project itself evolve addressing them. Trying to do so retrospectively is likely to result in sub-par approaches that are not able to materialise all the benefits a project could have, or even inadvertently causing harm. This could have negative effects for the projects and its stakeholders, especially in the form of reputational or even legal damage; or for the citizen scientists, their community, or environment.

Projects will have inherent risks to participants, which can constitute anything from inadvertent exposure to harmful materials while collecting samples, to exposure of sensitive personal information. Participants should be made expressly aware of the risks and mitigation strategies that may affect them prior to commencing their engagement in the project. The principle of informed consent to engagement and the risks it entails is vital; merely gaining acknowledgement does not suffice. The risks of engaging with a project must be explained in plain terms, such that the citizen scientists have understood the possible implications of their participation, and actively agreed to take these risks for themselves. It is also important to note that, as volunteers, citizen scientists will not be protected by the same institutional insurance and labour laws that are afforded to paid project staff. The specifics of regulations relating to personal liability and injury vary depending on national and institutional regulations, and should be checked and clarified before participants are recruited. This formalisation of risk assessment and mitigation should be approached in conjunction with best practice on safeguarding participants.

Projects also have a responsibility to safeguard the environment and those inhabiting it. Without proper training, there is a risk that citizen scientists working in sensitive ecosystems could unintentionally do harm to their objects of study or the surrounding environment (Palmer et al., 2020). Furthermore, data collection alone, without adequate links to the social context, has the potential to have an unexpected negative impact on environmental health. The higher capabilities of citizens to monitor environmental factors has been suggested to lead to a scaling-down of monitoring by regulatory bodies (Goeschl & Jürgens, 2012). The Safecast project was a low-cost radiation monitoring project which arose in response to the Fukushima disaster. While it was a success story in terms of citizen engagement and data collection, due to a complex interplay of different stakeholder aims, it led to citizen scientists counterintuitively collaborating with nuclear lobbies to downplay the extent of landscape radiation poisoning (Polleri, 2019). Research can also cause other forms of unforeseen harm: A study involving the introduction of fines for parents who picked their children up late from a day-care centre ended up worsening parents' behaviour, as the fine was perceived as a price for a service, which the day-care centre was unable to revoke (Gneezy & Rustichini, 2000).

A thorough risk assessment should be made after stakeholder analysis to pinpoint "flashpoints": contentious topics or those that could create a strong emotional response, topics that have the potential to be traumatic or triggering. Mitigation measures can include having an observer or facilitator present, or setting out / co-creating guidelines for discussions that are shared with all participants in advance.

Lastly, citizen science research should ensure that it is not "extractive" - it should ensure that the project benefits not only an organisation or researcher, but also the community the project engages with. Projects should also consider that, if their community is diverse, different members of this community may have different expectations, depending on their culture and lived experience.

Professional researchers may have access to ethics boards or review processes that help them conduct these risk assessments, identify issues and devise mitigation strategies. This may not be the case for citizen science projects, who need to find alternative ways to ensure their assessments and strategies are sound. One simple way of doing this would be to co-create the risk assessment with their participants, or share it with some of their stakeholders. We provide a research ethics checklist that can help projects work through these questions in a structured way. Project owners should be aware that this process of identifying, assessing and mitigating risks can take considerable time, and therefore needs to be planned into the overall timeline of the project.

Guidelines & recommendations - Research ethics checklist

Questions to ask in your citizen science projects to consider ethical implications

- What is it that you want to do? What is the goal of your project, and how do you plan to achieve it?
- Who will be involved in your project? Who will participate, and who will be affected, directly or indirectly?
- Do any of the activities you plan have the potential to cause harm, either directly or indirectly, to your citizen scientists, or anybody else?
  Harm can mean many things, from making people uneasy, to causing discomfort or even physical injuries; or affecting people's reputation or livelihoods.
- How will citizen scientists and others who may be affected by it benefit from your project?
- Do the people who could be affected, either directly or indirectly, know about what you want to do and why? Have they given their consent, and had an opportunity to object?
  It is important to consider power imbalances in this context, for example if you plan to engage with people who are dependent on some element or stakeholder of your project, or if you work with minors or elderly people who may not be able to give informed consent.
- Will you collect any personal data, about your participants or others? Do participants expect anonymity? How will you ensure this?
  If you work with personal data, please read our guidance in the Data *section.*
- If what you plan to do made the headline of the New York Times tomorrow, would people be angry about it? Why?

Case study - Water Sentinels

The Water Sentinels project has a very close relationship to the small group of citizen scientists they work with. When the project began, through discussions with the ACTION team as well as their participants, they started to think about the potential risks to their participants. This was largely driven by ACTION's requirement to ensure participants gave informed consent to their engagement, and were informed about any risks inherent to their participation in that process. Asking for a signature to state consent gave the participants' involvement an 'official' perception it did not have before, and thus caused a more in-depth conversation about consent and risks of participation.

Participants both collect current data through water samples, but also contribute historical data about pollution events that they have witnessed. The historical data collection was completed by the project team, due to privacy concerns of participants, who were uncomfortable sharing potentially sensitive issues with volunteers. This necessitated that the project team speak to all participants individually or in small groups, rather than implement either data collection by citizen scientists, or in large group settings. For similar reasons, the project team and the participants decided that it would be safer for the citizen scientists not to appear in any materials about the project, such as videos, or be acknowledged by name. Participants perceived being publicly linked to the project as a risk, as their contributions might expose polluters

in their local community, some of which their livelihood depended on; or cause conflict in their own communities. Participants were not comfortable with the possibility of retribution by either potential polluters or their communities if their contributions could be traced back to them.

These discussions initially caused delays and worries with participants, but also allowed the project team to work through these issues with the participants and make them truly aware of the risks, and therefore ultimately collect well-informed consent to the participation that was agreed, and may affect how they engage with research in the future.

Case study - Mapping Mobility

The Mapping Mobility project was led by researchers at a British university, which required them to submit their research methodology for an ethical review before implementing it.

While the project team had been trained in citizen science and engagement, the Universities' ethics committee had no such background. They were not familiar with citizen science as a practice, and raised many concerns about the projects' attempts to engage citizens in a variety of ways being potentially exploitative. This caused the project to make very clear in their setup and documentation exactly what citizens could do, and what benefit their engagement would have, to the research project, to themselves, and to the wider community. The main benefits for participants were the opportunity to acquire new skills (specifically in using GIS software), contribute to policy about mobility in their environment through data, and releasing funds for their community centre if they contributed a set, low number of data points.

Participants were aware of the potential benefits and what they were expected to do, as they had already been engaged with the project team in previous work. However, clarifying circumstances to the ethics committee and ensuring they understood why these practices were *not* exploitative and gave permission to carry out the research, was a serious hurdle. The delay caused by communication and assessment with the committee took several months, which caused the project overall to fall behind the ACTION accelerator timeline, which required the project to be completed in six months.

Safeguarding in citizen science

Participatory projects and citizen science are powerful methods that can have significant impact both on the project outcomes and those participating. This high potential for positive impact is matched by just as high a potential for inadvertent and unintended harm. Creating participatory projects and working with citizen scientists requires careful consideration, upfront planning and continued monitoring to ensure both the safety and continued wellbeing of those taking part (Resnik et al, 2015). Here we present some important considerations for safeguarding in citizen science, including the importance of the social context of the project, and the requirement to protect the rights of their participants. Further information, particularly relating to risk assessment and management, is available in the ethics section.

Understanding the social context of your project

Once the stakeholders for a project have been identified, the power dynamics within these stakeholders should be understood and acknowledged. Power dynamics have an implication on how responsibility and tasks are apportioned, and how different stakeholders feel they can act within a project. The designation of responsibility within a project depends on the organisational structure - how project organisers and initiators interact with each other. If a project is hierarchical in structure, the responsibility for safeguarding falls clearly within the purview of the core project team. In all cases, the principle of informed consent to engagement and the risks it entails is vital; merely gaining acknowledgement does not suffice. The risks of engaging with a project must be explained in plain terms, such that the citizen scientists have understood the possible implications of their participation.

Intellectual property

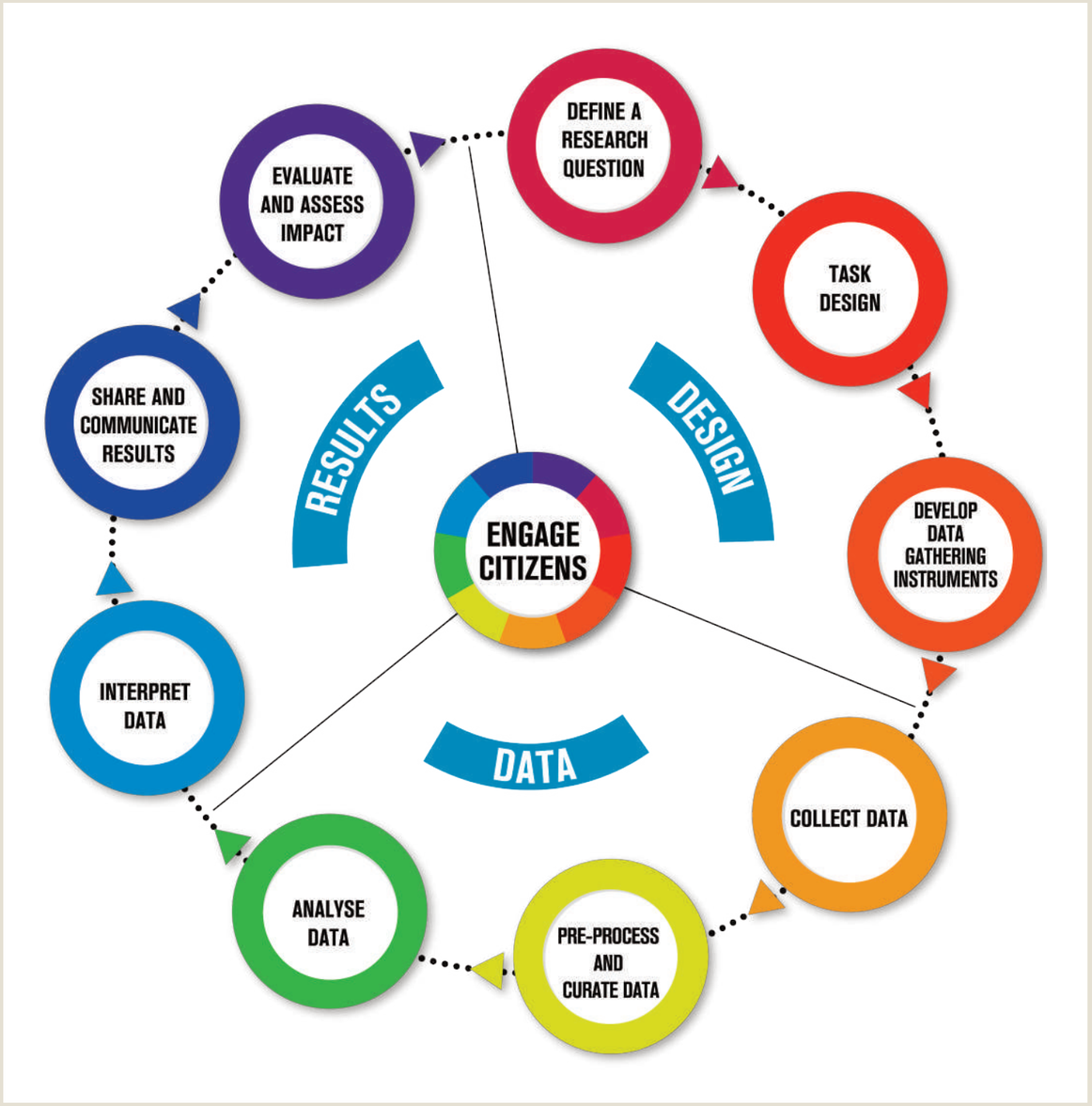
It is important to understand the differences between volunteering and professional or paid engagement with a project. As unpaid volunteers, citizen scientists donate their time and efforts to a project according to the motivations and incentives outlined below. Important to the continuation of this exchange is fairness in relation to how Intellectual Property (IP) rights are handled within the project. IP describes the ideas, conclusions and innovations that come from a project. Formally funded projects have enormous discussions about how IP will be handled before a proposal is submitted, yet in CS projects the issue is often neglected. There is an implicit trust within a CS project that IP will be handled fairly. However, while there are obvious reputational repercussions if this trust is broken, projects rarely implement safeguards to prevent this. In fact, it is precisely because the citizen scientists are volunteers that they are the most vulnerable to losing their IP: lacking contracts, they fall outside many of the legal safeguards developed long before CS was a consideration (Guerrini et al., 2018; Ottinger, 2017). Many volunteers may be unaware of issues of intellectual property and the potential value of their contributions (Standing & Standing, 2017). Indeed, it is this lack of understanding and information that poses arguably the most significant ethical risk for crowdsourced activities such as citizen science: scientists and project administrators hold all or most of the power in such initiatives by virtue of their greater knowledge of — and influence on — the crowdsourcing landscape (Martin et al., 2017).

The situation is clearer when it comes to copyright; although still varying from country to country, most often the CS will retain their copyright of any documentation and materials that they produce during the project, as long as they have not agreed to hand over these rights. This, however, can cause complications in publishing project results. Potential for copyright disputes can be avoided by having a policy of publishing all content from the project under one of the many Creative Commons licences that permit reuse of the material without handing over copyright.

Managing commitment and capacity

Operating outside of established safeguarding structures, it is important to be aware of the risk of overcommitment to a CS project, particularly in the case of projects where the citizen scientists are particularly invested in the outcomes - for instance where the intention for engaging is to effect change in the citizens' environment. This risk can be addressed at multiple points in a CS project. In designing the project, the initiator manages the expected workload and time commitment of citizen scientists through levels of participation that can be navigated so that a participant who is overwhelmed can scale back the amount of time or energy they devote to the project. To some extent, and particularly in larger projects, the risk of burn-out in a project can be reduced by effective communication strategies such as rewarding and acknowledging contributions and commitment to the project (Land-Zandstra et al., 2021). In smaller projects where there may be additional pressures from interpersonal relationship expectations, it is important to keep personal channels of communication open and to take the initiative in checking on the welfare of participants.

RESEARCH IMPLEMENTATION



The implementation of a citizen science project will rarely be as linear as our graphic representation suggests. There will inevitably be some back-and-forth between the individual steps, such as defining the research question and design - in practice, these are commonly refined together, so as to ensure that question and design are compatible and feasible. On the other hand, not every type of project will need to go through all of these steps, and even when they do, what needs to happen at each step, and who is involved, will differ. We will discuss how different types of projects solve this as we go through the steps.

CITIZEN ENGAGEMENT

Engagement of citizens is at the heart of participatory science. Citizens can engage with projects in many different ways throughout the entire participatory science lifecycle: They can initiate projects, formulate research questions and hypotheses, collect, analyse and interpret data to answer them, learn about the scientific context, communicate the results of the project to policy makers and relevant stakeholders, talk about the project on social media and other platforms, or engage with others in their own and the scientific community (Bonney et al., 2009; Phillips et al., 2019). While many projects will have some kind of link to the scientific community, others do well without such connections. For example, Noise Maps was conceived by citizens, but had support from sound experts at a local university, while In my backyard developed and executed their project, collected and analysed their data together with citizens and a local research centre.

Any participatory science project will engage citizens at some or all stages of their lifecycle. The specific form citizen engagement takes will look very different depending on the type of project, who initiates it, what it focuses on, and what stage of the lifecycle it is in. If the project is not initiated by citizens or has no direct link to the community it is embedded in, engagement should be the focus of project owners, to ensure citizens' voices are heard and taken seriously.

Another dimension of engagement concerns the capability of CS projects to act as a community, enable exchange among peers and collaboration. In this context, national associations for citizen science are an important resource. Many EU countries have formal or informal networks of practitioners. Moreover, another important point of reference is the European Citizen Science Association, which organises bi-annual conferences, distributes a regular newsletter, and is organised in several thematic working groups that members can join. In addition to specific CS groups, CS activities often grow out of Hacker or Maker spaces and FabLabs, which are connected to global networks of DIY Science practitioners. A good place to start is the Hackteria.

Guiding Questions

Questions projects should ask when planning their engagement strategy include:

- Who will be affected by the research, and who will be interested in it? What other stakeholders are there?
- Who do they want to engage in the project? How can they reach these individuals / communities?
    - Who is not included yet, who will be hardest to reach and why, and how can they be included in the project?
    - What are the limitations of the project if not all stakeholders can be involved?
- What will motivate people to engage in the project?
    - Should engagement focus on intrinsic or extrinsic motivation?
- What is the best way to engage people for this specific project?
- What tools would be useful to achieve this?

ENGAGING INDIVIDUALS & COMMUNITIES

Who are the citizens that need to be engaged? This will depend heavily on the kind of project, and the stakeholders that are involved. For example, while all of the ACTION pilots engaged citizens and/or local communities, some of them found that it is also beneficial to engage potential polluters, such as owners of fishing vessels (for water and air pollution Sonic Kayaks; see case study below), or catering suppliers (for plastic / soil pollution - Citicomplastic).

One key aspect of engaging participants is to ensure the diversity of the group. There are many benefits to diverse groups that are not limited to citizen science: They tend to be more creative, more productive, and perform better in general (Page, 2014). In citizen science specifically, diverse teams can help to develop new approaches, see issues from different angles, and ensure that project results are useful for a wider proportion of the communities they affect (Intemann, 2009).

The best way to ensure a group is diverse, is to actively reach out to groups who could or should be included, and make the project accessible to them based on the circumstances of their lives. For example, recruiting on social media will not be successful at reaching citizens with limited digital literacy; offering meetings only during the work day is unlikely to reach citizens working in 9-to-5 jobs; planning all interactions in the early evening will make it hard for parents to engage. We recommend mapping the stakeholders for a project, including potential barriers to engagement, and creating strategies to engage each group separately. While there may be some overlap in how the majority of citizens can be reached, special care needs to be taken for those participants who are hard to reach. Davis et al. (2020) recommend three ways to engage diverse citizen scientists:

1. Consider existing relationships and community-identified problems as participant motivation
2. Design participant methods to include personal support structures and relationship-building
3. Design for participant time and technology access as significant limitations to participation

Projects can engage with individuals, such as participants of Loss of the Night, who download an app and submit their measurements independently, or projects can engage with communities, such as AZOTEA the project working with a local astronomy club. Engagement can be a one-off activity to complete a specific task, such as in the Noise Maps project, where participants recorded the soundscape of their city to preserve it, or in continuous studies, such as the Dragonflies and pesticides project, where volunteers have been monitoring insect populations for decades. Engagement may also change over time, with different groups of citizen scientists involved in different stages of the projects, e.g. one group collecting data, and another classifying it.

Tool - ACTION volunteer engagement roadmap (pdf version)

ACTION developed a volunteer engagement roadmap, meant for everyone who wants to increase participation in a citizen science project. The tool supports the development of strategies to increase volunteer participation, as well as practical advice on how to implement these strategies. Users can add comments that can be integrated in the tool.

Tool - Basic tools for engagement

CS projects can use many tools to engage with their community, some of which are listed below.

- Mailing lists and newsletters are common entry-level communication tools that help bring a community together. Free and easy mailing lists can be set up for example on Google Groups, or Mailchimp .
- An online presence is important to represent a project and inform stakeholders about their goals and achievements. Simple websites can be set up for free on blog platforms such as Wordpress .
- Social Media is of course a key tool in any online engagement, and projects should explore whether they want to be represented on common platforms such as Facebook, Twitter, Instagram, YouTube, TikTok, Snapchat, or LinkedIn. Which of these platforms is most useful will depend on which kind of audience the project wants to reach.
- Surveys can be an easy tool to engage participants, stakeholders, and the wider community of a project. Common tools to set up and run simple surveys include Google Forms, Microsoft Forms, or SurveyMonkey.

Depending on the project host and organisational structure, projects will need to consider the ethics and privacy rights of their target groups when they process their data; we explore this in more depth in the ‘Data’ section below.

Diverity Guidelines

These Diversity Guidelines are focussed on inclusion within citizen science projects. They provide practical advice on how to design your project to be inclusive to a wide range of community stakeholder. They are further explained in this video.

Brainstorming Diversity Workshop Materials

These workshop materials help to understand a citizen science project’s design affordances, map stakeholders, and identify opportunities to include missing stakeholders in the project’s design.

Case study - Sonic Kayaks

The Sonic Kayaks team participated in the ACTION workshop on diversity in March 2020, which led them to realise several ways in which they could expand their engagement and accessibility. Following the workshop, they revised their budget and set some of their funds aside to hire an accessibility expert to review their website. As the project works with participants with visual impairments, this helped them make the website and their resources more accessible to their current and potential future participants. The project also found that they should not only be working with participants to measure pollution, but talk to and engage the polluters, such as owners of fishing vessels, who have significant agency when it comes to water and air pollution.

MOTIVATIONS & INCENTIVES

Citizen science projects, especially those that involve citizens from the outset, need to align their activities with the motivations of their (potential) participants, and find ways to motivate them to engage. There is a lot of best practice as well as research on how participants can best be engaged and motivated, what motivates them, and what kind of incentives work under which circumstances. Many studies (e.g. Schaefer et al., 2020; Phillips et al., 2019; Lee et al., 2018) found that citizen scientists are motivated to engage in CS projects for a number of reasons, both intrinsically and extrinsically: They want to support research, are interested in local issues and the technicalities of the project, raise awareness of the problem, and achieve the projects' goals.

We found in one of our own studies on the TESS photometer network that citizen scientists were primarily motivated by their interest in the topic, their desire to learn about it, contribute to the research, data and public awareness on the topic, and because it was a good thing to do, which made them feel good about their engagement (Re Calegari et al., 2020). In a later replication of this study, we found that some factors were consistently highly motivating, such as the possibility to do something meaningful, the perception of supporting scientific research, the expectation to learn about the specific topic, and the possibility to raise public awareness and make pollution data available. Other factors did not support motivation, including being forced to participate, receiving recognition and status due to participation, or regular participation in citizen science (Reeves et al., 2021; Maddalena et al., 2022).

Participants' motivation is also affected by the organisational structure of a project. Where participants have more freedom to explore what they are interested in, they are also more motivated to do so (Tinati et al., 2015). On the other hand, in hierarchical projects that are organised in a top-down fashion, citizen scientists will be less motivated - and thus such projects need to work harder at engaging and sustaining their participants' motivation (Tinati et al., 2017). What motivates citizen scientists also changes over time, and thus different activities or messaging may be required to engage them throughout the lifetime of a project (Lee et al., 2018).

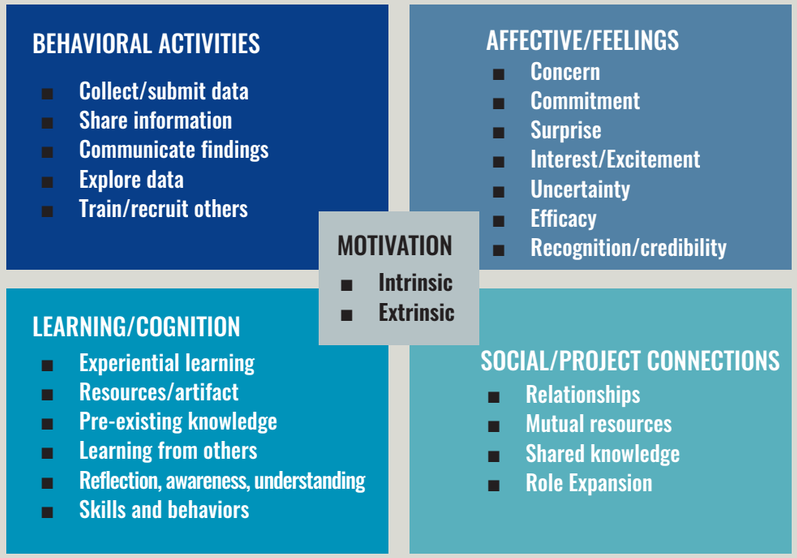


Figure 2: Proposed Dimensions of Engagement Framework, by Phillips et al., 2019

Another factor that influences participants' engagement is their self-efficacy - the feeling of competence they have to perform a task (Bandura, 1978). Feeling anxious about their own ability to perform the tasks correctly, or them not being accurate, smart, or capable enough, leads to fewer contributions or even stopping their participation altogether. On the other hand, the more expertise and prior experience in a subject participants have, the more contributions they make and the longer they participate (Aristeidou, 2017; Eveleigh et al., 2014; and Segal et al., 2015). Fortunately, participation in citizen science itself has a number of positive effects on participants, including enhancing their knowledge, making them more aware of the issues at stake, and empowering them to speak or even take action to address them (Schaefer et al., 2020).

Projects may already be aware of what kind of participants they will attract, how they can be engaged, and what motivates them, which they should validate at a later stage. They should explore what motivates their participants, for example through a survey, so they can either align their participant's interests with what the project requires, or consider incentives they can offer. This can mean providing explanations and options for participants to indicate where they are insecure and get support, to overcome participants' anxiety (Eveleigh et al., 2014; and Segal et al., 2015). Reeves & Simperl (2019) found that direct responses to contributions from both the community and involved scientists have a significant impact on how much participants contribute.

Projects should also consider different kinds of contributors, as not everyone will be able to make the same volume or quality of contributions, and to recognise that not all participants will want to be engaged in all stages of a project. Where possible, they should allow for both highly active participants, as well as those who can drop in and out and pick up small tasks, allowing each group to engage as much or little as their availability and interest allows (Eveleigh et al., 2014).

To continuously engage with a community, there are several practical things projects can do:

- Increasing self-efficacy: Projects can alleviate their participants' anxiety by increasing their self-efficacy. Ways to do this are to make people feel like they are doing a good job, by giving them clear instructions in tutorials etc., to let them know it is ok to make mistakes, and to allow them to flag uncertainty when doing their tasks.
- Social interaction: Although social factors are not always the most significant motivation for participating, they can be a significant motivation for a portion of participants. Lack of social interaction can also be a reason to stop participating. Social interaction in a citizen science project has two main forms: between participants and project coordinators or among participants. Newcomers observing longer term participants is an important aspect in them becoming full participants, because it allows them to determine if they want to participate, and how to participate and is critical for participants transitioning to longer term engagement.
- Framing and recruiting: Finding the right framing for a project can increase participation by helping to find the right audience. Projects should formulate what their problems, goals, moral evaluation, and messages are. Recruitment strategies are important, and also very dependent on the kind of framing of a project. Examples of ways to recruit citizens are through CS platforms, by word of mouth, or by involving other institutes and organisations. Good project framing and recruiting can also lead to more appreciation and a sense of importance of the participants.
- Appreciation and importance: Appreciating participants and acknowledging the importance of their work can lead to increased contributions from participants. Projects can acknowledge the importance of participants' individual work or stress the importance of the project. Ways to do this are to give feedback, to acknowledge participants in the dissemination of results, or to give them more responsibility.
- Gamification: Gamification can improve participation and motivation. When implementing gamification elements, projects should be mindful of how they might bias the results: generally gamification does not increase data quality. Score-based systems that are personalised with individual goals are generally better rather than a leaderboard, which can make new and infrequent participants feel overwhelmed and unappreciated. We recommend using collective, intrinsic and progression-based gamification elements.

If the projects' tasks can be aligned with the intrinsic motivations of participants, this will increase engagement. If tasks cannot be aligned with existing motivations, projects should think about offering things that their participants may want, such as specific incentives, games, events, or credit. Co-design approaches can be particularly useful to align the activities with participants' interests, engage and motivate them, and help to enhance participants' self-efficacy and understanding of the topic, thus empowering them to engage more. We provide some practical tools to do this in the tools section below.

Toolkits on citizens engagement and co-design practices

Several other projects have developed toolkits for engagement and co-design:

- Siscode has developed a toolkit on co-creation in science, which gives detailed guidance on forms of engagement in the scientific process.
- The TeRRIFICA project has developed an extensive guide to engagement and co-creation, which includes recommendations, strategies and methods for engagement and co-creation in citizen science.
- The Scivil Communication Guide includes tactics and tools for identifying citizen scientists for a project and securing their initial and continued participation.
- The SPARKS project has developed a collection of activities for different science education and engagement events in their activity toolkit.

ACTION webinars

As part of the ACTION accelerator, the team ran several webinars on different aspects of citizen engagement in citizen science:

- A webinar on diversity and inclusion in citizen science, which explains why it matters, and gives some pointers on how projects can address the issue.
- A webinar on online community engagement, which discusses how online communities are formed and maintained.
- A webinar on motivation in citizen science, explaining what motivates participants, and how different forms of motivation interact.
- A webinar on sociocracy, explaining use of the governing structure in the Open Soil Atlas pilot.

Tool - Qrowdsmith

Qrowdsmith is a crowdsourcing platform which includes gamification components, such as leaderboards, badges, levels, and other functions that go beyond traditional crowdsourcing tasks. It is intended to allow you to achieve optimal engagement with participants.

Case study - Noise Maps

Noise Maps was initiated by a local community, and had strong links to citizen groups from the get-go. However, the project found that the areas in which they wanted to take sound samples included places with hardly any residents, and no resident citizen scientists - such as around the Sagrada Familia. The project managed to overcome this in two ways: They approached public institutions in these locations, such as libraries or schools, who could host their sensors. They also created a whole new way to collect data: Rather than positioning their sound sensors on buildings, they organised walking tours for volunteers, who carried sensors with them, and stopped to take samples at pre-defined locations. This not only gave them more data they would not otherwise have had, but also made the project more accessible during the pandemic-caused lockdown in 2020.

Case study - Mapping Mobility

The Mapping Mobility project used incentives to entice participants to submit data about their active travel routes. Rather than providing incentives on a personal basis, the project team decided to implement community incentives: For each participant who completed a set number of submissions, a donation would be made to the community centre. The funds were capped based on the project budget, and held and distributed by the local council, who was more than happy to support the project in this capacity.

Study - Open Soil Atlas

The Open Soil Atlas project started out with the assumption that participants, once trained through an online workshop, would be able to collect and test soil samples on their own. The project team presented the project, what they did and why, and how participants could contribute. However, this did not lead to the level of engagement they were looking for. The project team then pivoted to offline workshops, where they had the same educational content, and then went out together with participants to collect and test the samples together. These workshops were very successful, and subsequently implemented with different audiences, such as schools or community groups. Once participants have had hands-on experience in soil testing, they can then implement this knowledge by taking further samples and testing them on their own.

DESIGN

During the design phase, projects develop suitable data collection instruments to answer their research questions, an define tasks that participants will work on. The design of research tasks that individual participants can complete should be based on the overall research design and project goals. It should involve a plan for the research implementation as a whole, including data collection and analysis, and the role of participants with potentially different skill-sets at different points in the project.

Guiding questions

In designing their citizen science tasks, projects should consider the following questions:

- What resources do you need to implement and run this project, and how will you access them?
    - You could look into support or funding programs for citizen science, or look into free tools and resources that you can use.
- What expertise do you have, and what are you missing? How will you fill those gaps?
    - This could be by learning about aspects of the project yourself, by finding volunteers or paid services, or partnering with individuals or organisations who can provide them.
- Are there any individuals or organisations you could partner with, and for what purposes?
    - You could reach out to researchers at local universities, NGOs with goals similar to yours, or councillors with a political interest in the issue you are investigating.
- Where and how will citizen scientists be involved throughout the project? What contribution can they make? How will you engage with them?
    - Citizens could be involved only for data collection, for example by using an app you provide them with; or they could be involved in the entire process, advising the project on key questions and issues.
- What data do you need to collect to answer your research question? How much data will you need? What will you do with it?
- What is the best way to collect the data required to answer the research questions?
- What tools will you use to collect the data? How will you ensure data quality?

The task design includes details for the different kinds of contributions participants can make, and how. Not every participant will contribute at all stages and in all the possible ways to a project. Where and how they engage will depend on their skills, abilities, technology available, and motivation. Therefore, projects need to consider and design their tasks, so that participants with different backgrounds and in different situations can complete them. Task design, or the translation of broad goals into specific actions, requires an understanding of scientific methods and rigour, so the project can produce robust data for their goals.

These guidelines are high-level recommendations for designing and implementing citizen science initiatives developed by the ACTION team. They are based on research findings from within the ACTION project – to find out more, you can read the report of our findings .

1 Account for trade-offs
The use of citizen science entails inevitable trade-offs between the quantity of data, the speed at which data is to be gathered and the accuracy of the gathered data. When designing tasks, it is essential to consider and identify which of these factors is to be prioritised and take appropriate steps to safeguard this factor, while taking steps to mitigate threats to the additional trade-off factors. For example, if a project is to emphasise accuracy and quality of data submissions, the task completion time is likely to increase and this can limit engagement. It is important to then streamline and simplify the task completion process to support faster data gathering or take steps to encourage engagement to account for these trade-offs.

2 Account for technology
It is important to consider the technology and software that volunteers are likely to use to complete your task. Does the task need to support both mobile and desktop devices or is the task designed to be completed outside of the home? Does the task support multiple browsers? Wherever possible, support diverse technologies to lower any barriers to entry. If participants cannot access your task, then they are unlikely to put in the effort to overcome these barriers and continue contributing. If these barriers are technological, it is also possible that volunteers will not be able to overcome these barriers or will not know how.

3 Provide Context
Citizen science tasks can often be designed and implemented in such a way that they are trivial and simple for volunteers to complete. This is essential for encouraging accessibility and gathering high quality data, but can obfuscate or trivialise their research value, with potential to harm volunteer engagement. Tasks, project resources and educational resources should provide additional context on the value that volunteer contributions pose for the research process.

4 Provide Feedback
While citizen science tasks are generally designed to be easily understood and completed by all participants, not all projects are able to achieve this. Moreover, even where tasks are otherwise easily understood, participants want and need feedback on the accuracy of their responses and the value of their contributions to scientific research. Providing feedback to participants — either within tasks or through features such as forums or newsletters — can encourage engagement.

5 Solicit Feedback
Tasks should not necessarily remain static. The design process involves a number of assumptions and trade-offs which may not align with participant expectations. Soliciting feedback from participants is key to ensure the needs of all stakeholders are met, with potential for increased task quality and engagement, as well as volunteer engagement.

6 Avoid Ambiguity
While the requirements and processes involved within a task may be clear to task designers, these do not necessarily align with the understanding and motivations of volunteers. Support participants through the task process with clear instructions, using discrete, clear questions and limit the need for personal judgement. Consider offering multiple choice answers rather than free text responses, for example.

7 Consider Time-scales
While citizen science is an effective way to gather large volumes of data for scientific purposes, volunteer engagement is sporadic, asymmetrical and often brief. It can therefore take a significant amount of time to gather larger datasets. This can be offset by focusing on restrictive, limited-time activities such as BioBlitzes, where volunteers are asked to gather or analyse data over a short period of time. While this approach can be very effective, it is less effective for tasks with more longer-term aims such as public engagement and education. It is essential to consider the implications and long-term aims of the approach to be used and which factors are most important — is it essential to gather data quickly or in large quantities? Do the research aims warrant longer term engagement and community building or is one off engagement desirable?

Sometimes the reality of a citizen science - or really any research - project is different from the expectation. Therefore it is important to be flexible while the activities are ongoing, to ensure the main project goal is achieved. However, it is necessary to specify that sometimes the results are more exciting than expected, and they could push the team to plan further activities. It is important to understand the difference between the scope of the current project goals and resources, and possible future initiatives.

Tools supporting task design

Zooniverse

Zooniverse is an online citizen science platform that allows users to classify images or sounds generated by other citizens. The Zooniverse Project Builder is a free and easy to use tool that allows anyone to quickly and easily design, implement and launch their citizen science project. The tool supports four task types and assets including images, videos, text and sound files. If desired, upon completion of the design and beta testing process, projects can be launched to the main Zooniverse website to recruit from potentially millions of volunteers.

Prolific

Prolific is a paid microtask crowdsourcing platform that allows anyone to quickly and easily recruit participants from a diverse, international pool of hundreds of thousands of crowdworkers. It is easy to use and interfaces with a number of common research software packages such as Qualtrics, Gorilla, Google Forms and Survey Monkey. Simply design your study, upload it to the internet and then design and deploy your Prolific task. The Prolific website features a detailed getting started guide and help centre which can help with everything from setting up your task to ensuring data quality. Unlike some other platforms, Prolific enforces a minimum rate of pay, ensuring ethical treatment for crowdworkers, while verifying and monitoring workers to improve the quality of the data gathered by workers.

Citizen Science Projects Builder

This is a web-based tool that allows users to develop and implement data analysis Citizen Science projects. It features a web interface that requires limited technical knowledge, and little or no coding skills. It is a simple modular “step-by-step” system where a project can be created in just a few clicks. Once the project is set up, many people can easily be involved and start contributing to the analysis of data as well as providing feedback that will help you to improve your project.

Tutorials

ACTION pilots have developed a range of tutorials to guide their participants through specific tasks:

- Street Spectra has created a tutorial for participants to identify the spectra of common street lamps. It explains how to use the spectrograph they provide together with mobile phones to take pictures of street lamps, and then use the images to categorise the type of lamp.
- Dragonflies and pesticides developed a tutorial to guide their participants - who would already be familiar with counting butterflies or dragonflies on their transects - on how to collect water samples for the project.
- Students, air pollution and DIY sensing developed a tutorial for Air Quality projects in high schools to help others who want to set up air quality measurement projects. It includes an overview of the process they used, and materials developed for workshops and events.
- Tatort Streetlight produced a video of a workshop and slides for education about the effects of artificial light at night on the environment. The video presents a workshop about light pollution, the discussion with the students and the practical part in which the students created ideas for future public lighting. It is a tutorial on awareness increasing and stimulation for finding technological solutions for the protection of insects and environmental friendly roadway lighting. The workshop was held in English, using German slides.

Case study - Noise Map

The project was developed by citizens for citizens, and allowed for several routes to engagement. In workshops with participants, they co-created a data collection protocol, which helped to select points of interest for data collection, and designed their whole data collection process. Participants could further host audio sensors at their home, or engage through guided walks, where they would collect data at specified stops. These different routes were meant to allow citizens with different engagement preferences and available time to contribute to the project in the best way that was possible for them.

Case study - Citicomplastic

The project had planned to engage participants in the data collection and results phases. However, due to the pandemic-related lockdown in 2020, they had to adapt their approach. Instead of hosting composters on a farm accessible to a large group of participants, especially disadvantaged youths, they found participants who could host a composter and conduct the experiment in their backyard. Participants were asked to set up the composter, containing manure and bioplastic, with help from the project team. They then proceeded to take weekly temperature measurements and photos of the decay of the bioplastic.

Case study - Open Soil Atlas

The Open Soil Atlas project was developed by the FeldFoodForest initiative: A community project with the goal to plant a food forest garden on an abandoned airport in Berlin. They wanted to regenerate the soil, to bring edibility back to the city, and develop an edible landscape. While they explored the site, they found that they did not have access to data about the soil. Although tests had already been conducted, it was impossible for them as citizens to get access to this data, without going through a cumbersome request process. This motivated them to develop a project that would create soil data that would be openly available. They brought citizens and experts together to brainstorm which data would need to be collected, what their research questions would be, and how the soil data collection protocol should be structured. This helped them create a comprehensive set of information about the soil, while keeping it simple and accessible. They proceeded to put together a solution in the form of the Open Soil Atlas, which is built up by citizens, making both the platform itself and the data freely available to anyone who may need it.

Case study - Walk Up Aniene

The Walk Up Aniene project was born in collaboration between organisations, who ran round tables with local committees in Rome to explore the value of citizen science and environmental monitoring. A Sud as an organisation wanted to build the local capacity for citizen science, and develop a citizen science project on environmental monitoring experiences for some time, and was motivated by the ACTION Open Call to develop this idea further. Through their activities they met Insieme Per l'Aniene, who were in charge of monitoring the state of the Aniene Valley Nature Reserve thorugh a river contract, which allows rivers to be managed in a collaborative way with institutions and interested stakeholders. They had already developed a questionnaire that could be adapted for citizen engagement. They joined forces, and developed the Walk Up Aniene pilot together, which was conceived from the beginning as a citizen science project. It is linked with the larger «Roma Up» project, which engages citizens in measuring the water quality of the Tiber.

Citizen science apps

It is important to consider what the best way to engage with your participants will be, and whether a mobile phone app could be a useful tool to use. These decisions must be taken early on, as they can have a big impact on the resources a project needs. While apps can be useful to engage specific target groups, such as younger demographics, both development costs and timelines can be prohibitive. Projects should therefore explore carefully the resources they have, whether there is enough time in their planning to develop a custom app, and the implications for long-term commitment associated with apps, such as the need for and cost of maintenance. If budget and timeline do not allow for a custom app, there may be an app that can support the project's needs. The below graphic can help projects determine if an app is needed, and what steps they need to take to get to one that fits their needs.

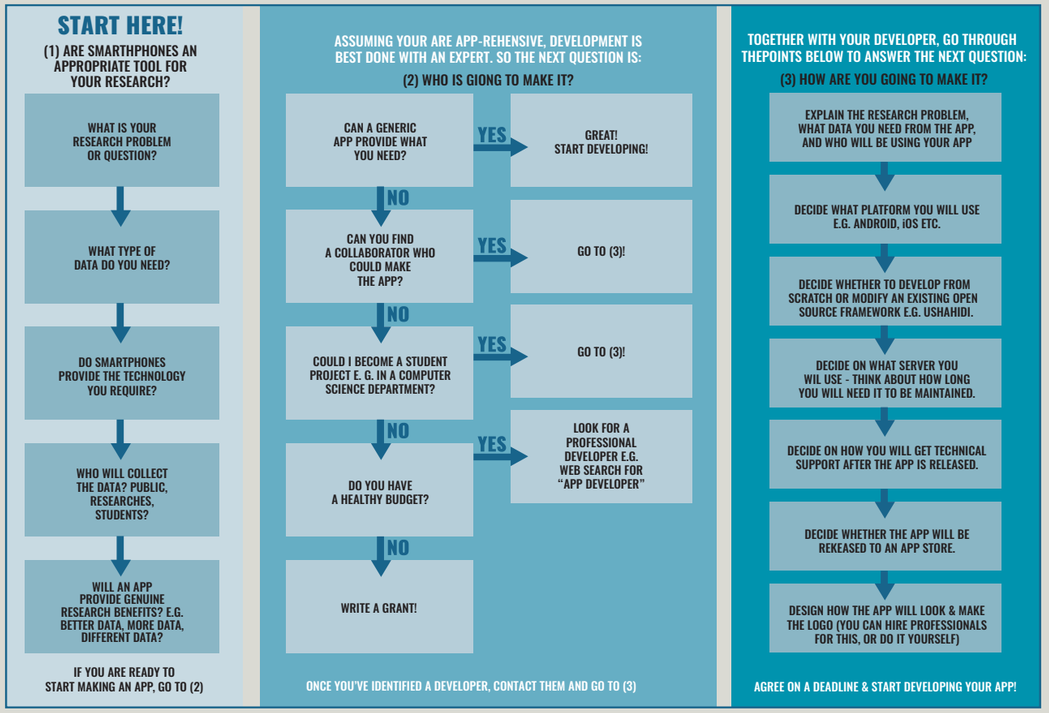


Figure 3: Outline of the development process, by Teacher et al., 2013

DATA

Guiding questions

For the collection and processing of their data, project managers should consider the following questions:

- How will citizen scientists be involved in your data collection and analysis?
- What support do citizen scientists need to engage with the data process in different ways, and how will this be provided?
- Have you completed a data management plan?
- How will you collect / store / process data? Are you planning on publishing your data? Where? How?
- Are you using any personal data, and if so, how do you comply with legal requirements such as the GDPR?
- How will you ensure data quality?
- How will you analyse your data? What will you do with the results of your analysis?

Data collection & analysis

In the data collection and data analysis stages, projects implement the methodology they have defined previously to acquire, curate, process, analyse and interpret their data.

Data in citizen science can be many things, and there is no one definition of it. For the purpose of this toolkit, we understand data to be the pieces of information collected for the purpose of generating insight. Depending on the project, data could consist of images, observations, descriptions, categorisations, physical samples, audio files, or a variety of other details. A dataset is a collection of data, and metadata is data about a dataset, which describes its properties, such as the title or description, who collected it, how it is licensed, etc.

Different kinds of data are typical for the different types of projects:

- In grass-roots citizen science, projects are often very local and collect data in a specific area, such as air quality measurements from sensors in homes or details about products used in the household. For Citicomplastic , data consisted of photos of compost, a measurement of the temperature, and description of its consistency and smell, taken every week. It was then analysed to demonstrate that home composting bioplastic was not feasible.
- With longer research projects where data is collected over long periods of time it is important that data is in a highly standardised format which allows it to remain comparable. For De Vlinderstichting, data consists of reported counts of butterflies and dragonflies from each walk of each participant on each of their transects in the whole of the Netherlands. This data is used by the national government to monitor species and environmental impacts of policies over time, and highlight urgent issues. Participants also collect water samples, which are frozen and sent to a laboratory for analysis, to identify pollutants. For Street Spectra, data consists of photos taken by participants with mobile phones and a spectrograph; they are submitted with metadata on the location and comments, such as the type of lamp as identified by the participant.

- For educators, data is not so much the driving force for the projects, as for the participants themselves, who collect and analyse it in order to learn about science, and understand a specific issue. For Students, air pollution and DIY sensing, data consists of measurements collected by students with their own air pollution sensors. They analyse it based on their own research design to understand the issue of air pollution in their environment.
- In online projects, data can be anything that can be processed digitally: Images that are submitted, or classifications of images in a variety of contexts; observations of species, or stars; transcriptions of texts, or descriptions of items. For Restart data workbench , data consists of records of repairs from their workshops, which is then analysed to approximate the environmental impact of those repairs, and drive policy on repairability of products.

Tools - Data Collection

These tools, developed and/or used by ACTION, can help projects gather the data they need.

- Coney is a survey tool designed to enhance the user experience when responding to surveys, with a conversational approach: on the one hand, Coney allows modelling a conversational survey with an intuitive graphical editor; on the other hand, it allows publishing and administering surveys through a chat interface. Users can define a graph of interaction flows, in which the following question depends on the previous answer provided by the respondent. This offers a high degree of flexibility to survey designers that can simulate a human to human interaction, with a storytelling approach that enables different personalised paths. We provide further guidance on how to use Coney here.
- Epicollect is an easy-to-use mobile application, which allows citizens to design their own forms to collect data, taking advantage of mobile functionalities such as geolocation, camera images, accelerometer, etc.
- The Virtual City Explorer is a web-based tool that allows projects to collect data about static infrastructure items in cities, by asking contributors to explore 3D environments on a page embedded from Google Street View.
- The Making Sense project has developed a Citizen Sensing Toolkit , including a wealth of activities for the use of sensors and other data collection activities in citizen science projects.

ACTION data webinars

The ACTION team has hosted several webinars on data processing:

- Webinar on the data lifecycle, which explains open data, open science, and the best way for CS projects to publish their data.
- Webinar on data protecion and processing, which explains how CS projects can work with data while complying with the GDPR.
- Webinar on data management with data management plans and data quality assurance.

Case study - Street Spectra

Citizen scientists in Street Spectra were primarily engaged in data collection activities. The project provides them with a spectrograph, which they hold in front of their mobile phone camera to take photos of light spectra of street lights when they are out and about. These photos are then uploaded to the projects' database through a mobile app (Epicollect), together with some metadata collected from participants' mobile phone, such as the date and time, and their location. The data is published directly onto a public database. The project team had planned to engage participants continuously in this data collection. However, the national lockdown in Spain in 2020 prevented all kinds of public outreach and educational activities. In the meantime, they decided to include citizens in data classification, by using the Zooniverse online platform, leading them to have two parts of the project to manage on two different platforms. Images and associated metadata had to be somehow copied from Epicollect5 to Zooniverse. During 2021, work was done to coordinate the usage of these two platforms by means of an IT infrastructure deployed by the ACTION consortium itself. The tool selected for the job was Apache Airflow, which allows to define workflows between IT systems. The tool by itself was not enough and had to be supplemented through custom developed connectors to interact with Epicollect and Zooniverse.

Data Management

ACTION recommends projects adhere to open science and the FAIR data principles. Open science commonly refers to efforts to make research outputs more widely accessible. Especially where this science is publicly funded, its results should be publicly available, so they can benefit further research, innovation, or citizens directly. Open Science also increases media attention, citations, collaborations, job opportunities and research funding (McKiernan et al., 2016).

The FAIR principles are designed to make data more widely usable, including machine-usable. They are good practice for publishing data in any context, including citizen science. The principles are:

- Findability: Data should be published with persistent identifiers (such as a URL), and include comprehensive metadata.
- Accessibility: Once found, both data and metadata should be easy and free to access, though authentication may be necessary.
- Interoperability: It should be possible to integrate the data with other data sources through common schemas, and to process the data with common applications.
- Reusability: Data should be exhaustively described and licensed to enable reuse.

In line with best practice from open science, the openness and availability of data should be considered throughout the project and should guide many of the data collection, analysis and dissemination decisions.

Tools - Data Management

Data Management Plan Tool

This tool helps you to generate a Data Management Plan. It is based on an online questionnaire, complemented with a chatbot (Coney) and specific questions for non expert users. This tool is focused on citizen science projects. We also provide a tutorial for the use of the tool .

Case study - Noice Maps

Noise Maps collects sound samples from both residential and public buildings, as well as guided walks. The data was collated by project host BitLab, who, together with researchers from their partner university, developed an automated data pipeline that processed all the raw sound data to generate train AI models to automatically detect different types of sounds in the recordings: cars, machinery, bird songs, etc., which together formed the soundscape of the neighbourhoods of Barcelona where the samples were recorded. Any human voices on the recordings were obscured, to protect the privacy of bystanders and participants. All data was uploaded to Freesound, a free, public repository of sound samples, from where it was visualised on maps, and can be used by other interested parties.

When collecting or working with data, projects should take special care to consider how they use personal data. This could simply mean details of their participants, which need to be stored safely; or data collected by participants, which may include location / GPS details. Any data that refers to a *natural, living, identifiable* person falls under the remit of the GDPR - the European General Data Protection Regulation. It doesn't really matter what happens with this data - whether it is only stored for safekeeping or used for analysis, the same principles apply. If the project controls the data, it (or its host organisation) will be considered as the *data controller*, which means they are responsible for ensuring that the data is processed in line with legal requirements. The main mechanism that allows projects to process data lawfully is the consent of the data subjects: Participants explicitly agree to their data being stored or used for a specific purpose (usually the participation in or contributions to the project). All details about which and how personal data is used should be captured in a data management plan.

Projects should complete a data management plan - however provisional - as early as possible. A data management plan describes the lifecycle of the data, and includes a summary of the data, its origin and format, how it maps onto the FAIR principles, how it is stored, processed and protected, and whether and how any potential ethical issues with the data are dealt with. The plan will help to understand what data is needed, how it is stored, what protection mechanisms are required for any personal data, and where and how the data is going to be published. It should be updated or replaced as necessary throughout the project's lifetime.

There are four main steps that citizen science projects must take to gather and analyse their data. There are additional data management principles associated with visualising and publishing results, which we discuss further under Results.

1 *Data collection:* First, projects need to identify the data they require, and where it can be collected. Data can be created by sensors, such as air pollution or sound sensors which citizen scientists operate, or by citizen scientists, for example when they record or categorise observations. When citizen scientists create the data, platforms like Epicollect are often used to collect it. A mini tutorial (see next section) is available to support projects in creating projects on both platforms. During data collection, projects need to take special care to ensure their process is compliant with data protection regulations, especially where personal data (such as contact details of participants) is involved.

2 *Data preprocessing*: After data is collected and available to the project, it may need to be cleaned, to remove 'noise', or invalid data, and ensure the collated data is in a format that can be used for analysis. Typically, data cleansing is necessary to identify and correct (i) intrinsic errors made by the sensors used to collect the data (e.g. GPS positions of mobile phones might be of low quality when there was a poor connection); or (ii) incomplete submissions or outliers, when data was collected by participants, which might affect the quality of the further analysis (e.g., poor-quality answers in surveys).

3 *Data aggregation*: Next, CS projects need to coherently group the data they collected. This is particularly relevant for classification projects. For example Street Spectra, in , users have to identify the spectra emitted by lampposts. For this purpose, they created a Zooniverse project to classify the different spectra. After a number of responses, the project is faced with a set of different values, and has to decide which is the correct one. There are a number of techniques to determine this, such as majority voting (which option has more votes) or the use of the Fleiss Kappa statistic. Another example are locations, for example of lampposts. Citizen scientists may generate this information, but submit different positions (latitude and longitude). It is necessary to reconcile these observations into a single one. In this cases, it is worth identifying if the different positions marked reference to the same lamppost; the position could then be reconciled by reducing the precision of the observations (removing some decimals).

4 *Data analysis*: The data analysis is the core part of a CS project, where the collected data are examined to try and extract high level information out of them, and ultimately respond to the research questions set out at the beginning. Prior experience or external expertise can be particularly helpful during data analysis, since solid knowledge of the methods and their practical application can speed up the analysis itself, and reduce the probability of errors. However, citizen scientists may also want to understand and be able to analyse the data for themselves. In many CS projects, data analysis can also include analysing the contributions by citizen scientists. For example, projects could investigate the number of errors a contributor made with respect to some set standards, or focus on inter-annotator agreement, to measure how well a group of annotators can make the same annotation decision for a certain category.

Data quality

Alongside the above data processing, citizen science projects should consider the quality of their data, as poor quality data cannot satisfy the purpose for which it was collected. To ensure the quality of their data, projects need to understand what could affect it. This could be very obvious (e.g., training citizen scientists to make them familiar with data collection protocols), or issues with the data could be discovered during data collection (e.g., evaluation scales are too subjective and data collected by different citizen scientists are not comparable).

Our own studies highlight that some indicators are more frequent in CS projects, such as completeness (for geographical coverage, task/observation, number of functioning sensors/sampling), accuracy (for equipment, expert's acceptance, instrument calibration), timeliness (for time frame, scale, resolution, etc.) and consistency (depending mostly on volunteers' preparation). We identified suggestions on the most common causes of bad data quality in citizen science initiatives, and data quality improvement activities that were applied across projects, despite the different topics they covered. They included the improvement in the volunteers' training, sensors or toolkits' instruments and manuals, constant review of data acquisition activity, improvement in internal communication, integration of activities from different volunteers, increased acquisition in uncovered areas, etc. (Baroni et al., 2022).

Another important aspect in data quality assurance are the dimensions to be considered, such as the completeness, accuracy, timeliness, consistency, and accessibility of the data. Projects should consider which dimensions are relevant for them depending on the nature of their data. It is good practice to define indicators for each dimension and measure them, to check whether there are any issues. If issues are found, ad-hoc activities can be designed to improve data quality. ACTION created a template to help citizen science projects to analyse data quality and to improve it.

Tools - Data quality

Data Quality Assurance Template

This template is produced to guide projects to continuously check their data quality throughout their lifetime. It offers instruments to evaluate possible causes of low quality in data, a way to create ad hoc indicators and how to measure them, and a list of activities to improve the indicators.

Data Quality Resource Compendium

Developed by a specialist team within the Citizen Science Association, this compendium offers a wealth of guidance documents, manuals, and workbooks for quality control and assurance in citizen science projects. Each entry provides a link to the resource, information about the authors and intended audience, and which aspects of the data management cycle are addressed.

Guidelines - GDPR Checklist

You can use this checklist to confirm whether your use of data conforms to the European General Data Protection Regulation. The website includes a wealth of information on the use and protection of data.

Case study - Tatort Streetlight

Citizen scientists in Tatort Streetlight are asked to collect and identify insects. The collections are taken using insect traps, and citizen scientists also collect associated metadata, such as the time of the collection (start and end date), type of the trap (emergence trap for emerging insects from water bodies, eclector traps for flying insects at street lamps, or light traps for flying insects attracted to UV light) and the location (one of four study areas or an experimental field site). Citizen scientists use these collections to identify the specimen based on their insect order. The sorted specimens are stored in separate vials. These activities are also used for education within workshops, supervised by project coordinators, to present the differences of insect orders and biodiversity caught at street lights to students. Citizens science experts further identify the insect family or species. To identify the insects remotely, e.g. at workshop facilities or if they took parts of the insect collections to their private homes, citizen scientists can use an epicollect project or a handwritten template. So far, the entomologists and workshop groups preferred to use the templates, but as the participation is growing the Epicollect platform will be a useful tool.

Case study - Restart data workbench

The Restart Data Workbench project works on data that is collected by volunteers, in repair workshops across Europe. Citizen scientists are engaged in online microtasks, to classify the types of faults in selected products. Restart had already worked with microtasks for citizen science engagement, to see whether people that have had other levels of engagement would transition to those tasks, or whether they could engage new people who might not feel they have the skills to be active in a repair community per se. One challenge with this work was that the data collected at the workshops was often quite messy, which meant that it needed to be prepared for use with citizen scientists.

Restart engaged citizen scientists in classifying this data, because it allows people that are already part of the initiative to be more engaged, and use their experience to be part of the change they want to see, and become more aware of the wider implications of their engagement. Equally, it helps to improve future data collection, and increase interest in collecting more data in the community. Lastly, it is a more sustainable approach than having analysis being conducted by single professionals. Having multiple citizen scientists look at each record also enriches the validity of the data.

RESULTS

Guiding questions

Concerning the results of their research, project managers should consider the following questions:

- Which specific outputs will the project produce? This could be a report, an open dataset, an academic publication, a flyer to inform citizens, a business model, or many other things.
- What are the short term and long term social, economic, political and environmental impacts of your project?
- Who will be interested in these results? Who should be interested?
- How will you communicate your results to these groups?

At the end of their implementation work, projects will want to share and communicate their results, and evaluate their impacts.

Project outputs are resources that the projects produce based on their work, and the insight they generated. They can be many different things, such as data sets, reports, academic papers, online resources like maps or other data visualisations, software, or policy recommendations, to name just a few. These result types have different levels of quality and complexity, and will consequently lead to different types of impacts. For example, an open, well-documented dataset may have a large impact on research, whereas a set of well-formulated policy recommendations will be more useful in discussions with policy makers, and can lead to policy impact. Projects should have set out in the Problem framing phase what kind of outputs they want to produce, and what impact they want to achieve, which should guide how they go about producing and using their results in this phase. Projects may also find that unexpected results can lead to additional outputs.

How projects share their results will differ with the project type, as well as the audiences they want to reach. A grass-roots citizen science initiative focused on local issues is unlikely to have -- or to need -- the same reach as a national initiative funded by policy makers or government. It is important to consider the best way to communicate and disseminate relevant findings on a project-by-project basis. Citicomplastic created a public report and held a workshop in order to raise awareness of the issues they found with the composting of bioplastic. Noise Maps developed strong links to local communities and policy makers, which enables future discussions and projects about the issues they are interested in. To achieve wider reach, Sonic Kayaks made all of their outputs - data, reports and presentations - publicly available, to enable future research and support the open source community. Similarly, the students in Students, air pollution and DIY sensing presented the results of their research projects at a public conference, and partner NILU published a toolkit to enable others to replicate their work on a national website. Projects should carefully consider which outputs they have to share and how best to disseminate those.

Publishing data

Following the open science and FAIR principles described in the Data section, all results should be openly accessible, so they can inform future research and innovation. This helps to avoid unnecessary repetition of data collection or analyses for other projects.

To provide contextual details on the intended purpose(s) of gathered data, projects should publish not only their raw data, but also document completed and/or intended analyses alongside datasets. Wherever possible, this should include numerical results, data visualisations and the interpretation and analyses of results, such as a text-based report, which would be stored and disseminated alongside datasets (Roman et al., 2020). All details about the preprocessing of data should also be published alongside datasets and other research outputs. This may include a version history, a methodological description, or pre-processed versions of the dataset.

If stakeholders are to make use of data, then they must first be able to find and access any datasets and outputs. Any public dataset should include a permanent identifier such as a DOI (Digital Object Identifier, as well as a human readable and ideally machine-readable licence. Project web-pages should have clear, visible links to external datasets and other resources (Roman et al., 2020).

Data documentation tools

As well as the ACTION Data Management tool, there are two checklist tools which support documentation of datasets. Datasheets for Datasets and Model Cards are both templates consisting of a set of questions which should be considered and answered when preparing a dataset for publication. The answers are designed to prevent yes or no answers and cover issues that other stakeholders will need to be aware of if they are to use your data. Datasets for Datasheets is more general, while Model Cards is tailored towards machine learning and AI models.

Data publication tools

Zenodo is an Open Science platform, where data and any outputs can be stored, and receive a DOI. The ACTION Open Data Portal is dedicated to citizen science, and can be used to publish open datasets and their metadata, to make them available for the community to reuse, or keep track of the data produced/ consumed/ processed by our citizen science initiatives.

In the future, the ACTION Data Portal will integrate ACTION's ASSET Research Objects, which allows it to visually display the resources generated in each pilot, and the relations between them. A research object is an aggregation of research resources to exchange scholarly information on the Web. In a research object we can include papers, data, software, images, slides and any other research artifacts that were used in your research. This can be useful for other researchers (or CS projects) to reproduce and replicate your experiments in other conditions. One of the obstacles is that generating a resource object is a tedious task, which sometimes hampers its use . Thus, ACTION has developed a visual tool based on the tool ASSET to facilitate this task. Research objects generated with this tool may be published on other platforms like RoHub or visualised in our future Knowledge Portal (an evolution of our Open Data Portal).

Data visualisation tools

Grafana or Tableau are free tools for data visualisation. Projects can use them to create a large array of different visualisations from their data, such as heat maps, histograms, or even complete dashboards. Both come with extensive documentation and tutorials. Another easy-to-use online tool specifically for the development of dashboards is Infogram.

ACTION Webinars

The ACTION team has hosted several webinars on data, how it can be used and published:

- Webinar on the open data portal, which explains how projects can use Zenodo to publish their data and other outputs.
- Webinar on Grafana, which demonstrates a free tool projects can use for data visualisation, explains the main charts used to visualise data and the use of Grafana to display dashboards.
- Slides for a talk on communication and outreach, providing guidance on how to build a communication strategy and tools to use to reach specific target groups.
- The ACTION team also developed a webinar on impact assessment that explains in a synthetic way the overall approach and how to use the impact assessment canvas.

Case study - Sonic Kayaks

The project has published all of their data - survey results and measurements - and analysis on Zenodo, making them free for anyone to use. They also used their results (from a pre-ACTION stage of the project) to write a research paper together with their participants, which explains the concept of sonic kayaks and how their manifold usage opportunities: to monitor water quality, allow people with visual impairments to kayak, or as an art installation.

Case study - Dragonflies and Pesticides

The Dutch Butterfly Conservation publishes the data on pesticides collected by their citizen scientists on Zenodo. The method developed with University for Applied Sciences Leiden will also be made available through Zenodo in order to allow others to study these compounds in the environment themselves. Furthermore the activity itself raised awareness for an important threat to biodiversity that is invisible and often ignored.

Publishing insights

Projects may also want to communicate the insight they generated to the wider public, or to specific stakeholders they have identified at the beginning of the project or during their work. They should develop a communication strategy based on their stakeholder map, where they prioritise the most relevant stakeholders, and consider for each of them what they want to communicate to them, and what is the best way to reach them. This could include engagement activities for the wider public or local communities, like public presentations, talks, or webinars; or more targeted activities, like discussions with policy makers, giving evidence to public consultations, or discussions with students at a local school.

Communicating insights to different stakeholders requires projects to tailor their messaging depending on the target group. For example, policy makers are rarely interested in data and detailed justifications - rather, they want to know succinctly what they should be doing and why. Therefore, the best way to communicate results to them is in brief reports leading to recommendations for defined actions that can be consumed in the space of a coffee break. On the other hand, engaging the wider public may require explaining the basics of the research process, so that lay people can follow what the project did and what their results mean.

Guidelines for engagement

The Scivil Communication Guide includes many useful resources, but most importantly, walks citizen science projects through six steps to set up their communication plan.

The Data Refuge Toolkit is a downloadable resource collection, which enables projects to create public engagement activities. It was created by the Data Refuge project.

Case study - Ars ACTION Lab

Several of the ACTION pilots presented their findings at Ars Electronica in September 2020 - a festival that celebrates Art, Technology and Society:

- Noise Maps presented their findings on the sound heritage of Barcelona, and hosted a discussion on the nature of noise and its role in our culture.
- Students, air pollution and DIY sensing created a video for a workshop that demonstrated how to build air pollution sensors and measure air quality.
- Citicomplastic ran a workshop on the (issues with the) disposal of biodegradable plastic, and what citizens can do about them.
- Street Spectra hosted a workshop on the problem of light pollution, demonstrating how participants can use a spectrograph combined with their smartphone to help tackle the issue.
- Loss of the Night held a global observation campaign, followed by a workshop explaining light pollution and how it can be measured.
- Tatort Streetlight hosted a workshop on street lights and their impact on insect populations.

Summaries and videos of the presentations are available on the linked websites. All of them are fantastic examples for how citizen science projects and their results can be used to engage new, sometimes unexpected audiences.

Case study - WOWNature

The WOWNature project worked with the air quality sensor provider WiseAir, who supplied the sensors for the duration of the project, and also conducted the analysis of the readings, which was too technical and specific to be done by the project. The project team did support the analysis and report creation by providing specific local knowledge about the forests, such as where trees were cut here, or where barbecues take place. The team also provided information about the forest structure and stakeholders, based on its certification for forest management.
Wiseair analysed the data and provided a report about the analysis, that was written in a way that the citizen scientists could understand. A preliminary report was shared with the project and their participants, to which citizen scientists gave feedback, such as where details or conclusions were not sufficiently explained. The final report was then improved by Wiseair based on this feedback, and published by the project. In addition to the report about the analysis, the team has written and published another report about the whole WOWNature project that is used for dissemination, and may also support similar initiatives elsewhere, as well as the raw data collected through the sensor.

Assessing project impact

Assessing the impact a citizen science project has is crucial for any project, though the focus of this assessment might be different between short- and long-term projects. While for longer-term projects an impact assessment can be used iteratively to improve the project, for short-term projects it is a way to map the results in an accurate way and enable the project to communicate their results to different stakeholders. If a project with a single goal has achieved that goal, such as a change in local policy, this may serve as a single measure of success - but relying on this alone will miss out on all the other impacts the project has had. The overall goal of impact assessment is to bring about a more ecologically, socio-culturally and economically sustainable and equitable environment. ACTION has developed an impact assessment framework to assess the scientific, social, economic, political and environmental impact of citizen science projects, accompanied by supporting materials, all listed under Activities below.

Data collected through such an impact assessment methodology, along with a summary of the most relevant information on the project, can then be visualised in an infographic, such as the ACTION pilots Dashboard. An infographic is an effective solution to graphically narrate a story about the project's achievements, with the end-goal of helping the audience understand the context, the purpose of the various charts, and the progress made by the project over time. In the case of the ACTION pilots, it provides a set of intuitive, easy-to-use online widgets for different types of indicators, including socio-economic information, number of records gathered and validated, publication, events, etc. Besides infographics, impact assessment results can be described in ad hoc reports such as those included in the ACTION final impact assessment (Passani et al. 2022) or scientific papers (Grossberndt et al., 2021).

Socio-economic, political and environmental impact self-assessment methodology and tools

ACTION has developed an impact assessment framework and methodology to help citizen science projects understand what scientific, social, economic and political impact they have. The framework also helps CS project managers in analysing the transformative potential of their project, i.e. the degree to which the project can help to change, alter, or replace current systems, the business-as-usual in one or more fields such as knowledge production or environmental protection.

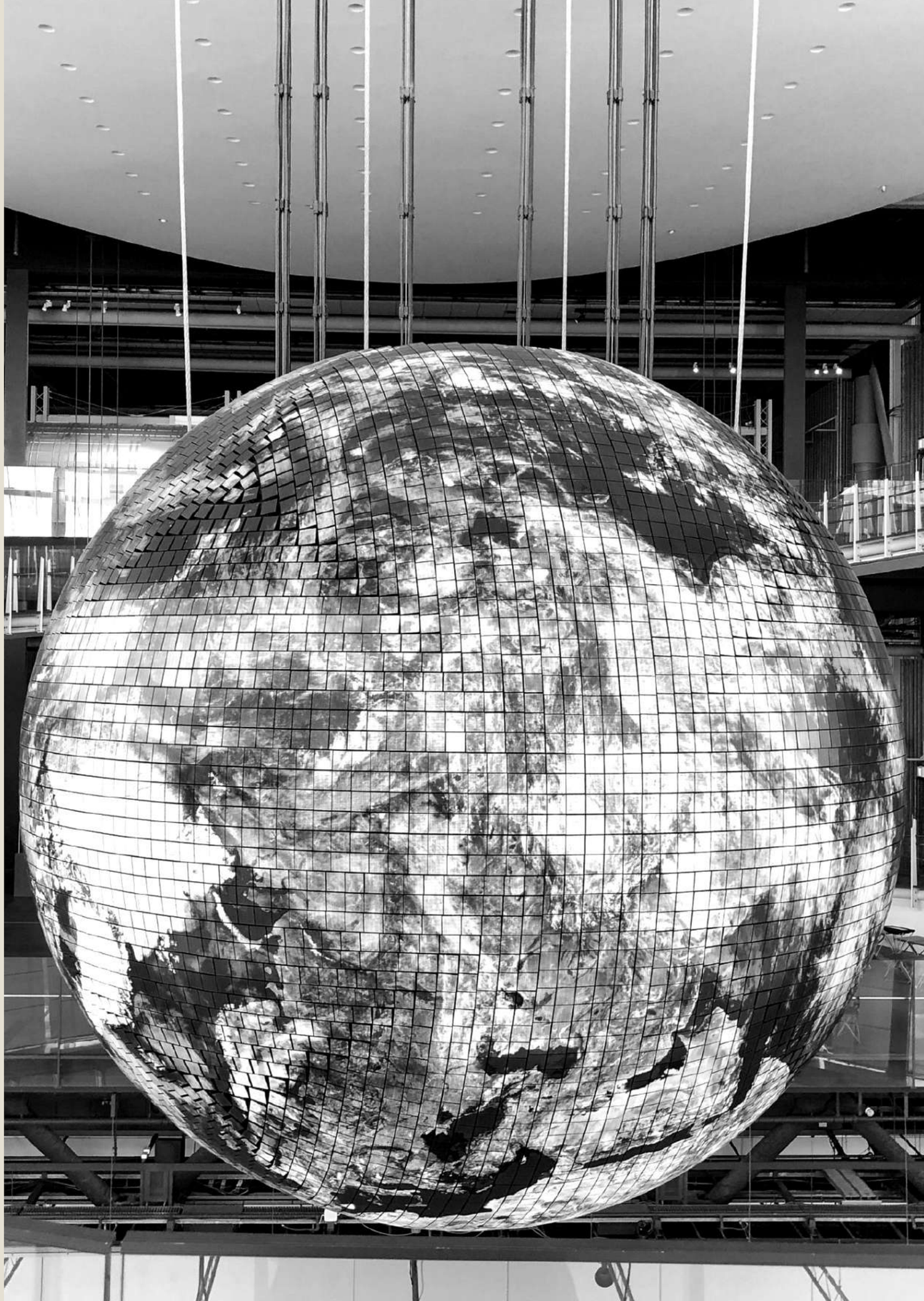
Following a mixed methods approach, the methodology is designed to be modular and flexible, in order to be adaptable to the specific characteristics of different CS projects. Indeed, not all the impact dimensions considered are (equally) relevant for all projects, depending on their nature, their specific focus and the level of citizen engagement.

The process for assessing the impact of a CS project works as follows:

1. Define the project outputs, stakeholders and relevance of various impact dimensions. This can be done by using the ACTION impact assessment canvas: a four pages graphic form, accompanied by guidelines supporting projects in filling it in.
2. Define an impact assessment process, and when and how to collect the required data. Projects can use ACTION's impact assessment matrix, which lists different variables for each of the impact dimensions, who needs to supply the data (project managers and/or citizens), and when (only at the end of the project (ex-post), or also at the beginning (ex-ante)).
3. Gather data. This can be done by using questionnaires developed and tested in ACTION.
4. Analyse the data and draft a report. An in depth analysis is available for the Students, air pollution and DIY sensing pilot in ACTION while shorter reports are available for each of the ACTION' pilots in the ACTION final impact assessment deliverable, together with an aggregated analysis (available on ACTION website and on Zenodo).

Case study - In My Backyard

CS projects can use the ACTION impact assessment canvas as a self-reflecting tool, as a guideline for discussing within the pilot team about the expected impacts and ways of maximising them and presenting them to their stakeholders. In My Backyard included the main concepts of the impact assessment framework in their final report. In a visual and communicative way they presented their main achievements in terms of social, economic, political and environmental impact.



LEGACY

Policy impact

Citizen science projects can engage with policy processes in several ways and thus generate different forms of policy impact. Generally speaking, policy impact occurs when decision-makers, policy makers, or politicians employ the data, knowledge and results from a citizen science project as the basis for their policies, political decisions and activities. With decision makers, policy makers, and politicians, we mean anyone in a governmental or semi-governmental organisation involved in strategic planning or decisions.

Impact on policy processes is achieved through the mobilisation of knowledge and information for policy making. Citizen science projects collect large amounts of data, and tap into local or experiential knowledge. This data provides policy makers and politicians with an evidence base to address (new) problems. Access to citizen science generated data is often considered cost-efficient. Furthermore, governments often do not have the type and extent of data provided through citizen science.

Citizen science projects can exert influence throughout the whole policy cycle:

- Agenda setting (new policy discourses and problem definitions): Citizen science projects can contribute to the problem definition and agenda setting stage of the policy cycle by triggering new policy discourses and concerns. In the past, CS projects have supported the identification of new environmental problems, such as farmland bird decline, and promoted issues such as pesticide use and intensive farming practices. In the "Botellon no me deja dormir" project in Barcelona, local residents were able to demonstrate how noise pollution was not a perception-, but a real problem. This helped to objectivize the level of noise tolerance which was previously considered to be subjective.
- Policy formation (new or changed policies): Impact on policy formation means that the data from the CS project was effectively used for new or changes to existing policies (e.g. regulatory, management, conservation actions). For example, as a result of a CS project that involved the recreational fishing community in Puget Sounds, Washington State, USA, federal managers changed regulation of the Endangered Species Act (ESA). Another example comes from the Entomological Society Krefeld, whose citizen scientists measured a 75% decrease of insects over 27 years. Publishing this data together with paid scientists, and its uptake by the media, resulted in new national insect policy.
- Policy implementation and enforcement: Citizen science can support policy implementation and enforcement, for example reporting breaches to relevant authorities, raising awareness and civic mobilisation. In the Sonic Kayaks project, citizen scientists measured pollutants in the water, coming from a big ship docked in the area. These results piqued the interest of the local council.

- Monitoring and evaluation of policy: Citizen science projects can contribute to the monitoring and evaluation of policies. It can especially address the data limitations of traditional monitoring programs, and thus enable the evaluation of the impacts of policy decisions. Several citizen science monitoring programs have been instrumental in informing the designation of protected areas (e.g. eBird, Seasearch,). The Common Farmald Bird Index is an example of recognized citizen science indicators for biodiversity monitoring in Europe, which is used to assess the impacts of the Rural Development Plans. Fresh Water Watch monitors water quality to monitor progress towards the Sustainable Development Goals.

Guidelines to achieve policy impact from citizen science projects

In addition to the policy recommendations, there are also steps that citizen science projects themselves can take. How can you ensure that the data, knowledge, and results of your citizen science project are taken up by policy makers? Here we outline five important steps.

1 Get in touch with policy makers

As the biggest potential for citizen science is to create local knowledge, it is usually better to approach local policy makers rather than national representatives. Local policy makers are much more concerned with and connected to the issues that local citizens have.

When having conversations with policy makers, it is best to talk about what you can do for them, rather than presenting the project in your own terms. For example, it would be better to talk about the polarisation that is happening between citizens and the local council about odour nuisance, and how involving citizens in gathering data could lead to constructive discussions, rather than explaining your project from A to Z and asking for funding for it.

Alternatively, a way to attract the attention of policy makers is via the media. If the project can publish some results that might be of interest or even shocking to citizens, policy makers might be more willing to collaborate. Whether this strategy works depends on the type of interaction with policy makers that is desirable: it runs the risk of antagonising them.

2 Align citizen science with policy priorities, agendas and processes

Influencing policy processes requires linking the citizen science project to existing policy agendas and processes. This means first, to understand the policy agenda, and its associated activities. Linking and communicating how the project relates to ongoing or emerging policy debates and priorities can attract the attention of policy makers. In this step it helps if the citizen science community is already aware of what policy makers find useful.

3 Clearly define roles and responsibilities in collaborations between policy makers and citizen science

The interests, needs and work procedures of policy makers, citizen scientists and researchers are not always compatible. It is therefore important that the aims and expectations, as well as roles and responsibilities in policy and citizen science collaborations are clearly, and jointly established. These roles, aims, and expectations are different for every collaboration, so it is important to define them. For example, the role of public organisations can range from being clients paying a fee for the service, to co-creating and implementing solutions, to providing institutional support and offering mentorship.

4 Continuous collaboration and engagement

Citizen science activities should link to policy-making processes in an ongoing way, for example by involving policy makers and civil servants in the citizen science project design. Ideally, policy makers and the citizen science community would iteratively and jointly discuss and communicate policy needs for data and knowledge and the opportunities that citizen science represents. Collaborations can be diverse, including lasting and formal partnerships but also more informal collaborations and engagement activities. Especially when working on specific policy issues such as environmental monitoring, policy makers can seek strategic partnerships with citizen science organisations. Face-to-face events are important for providing information and spaces for interaction, increasing awareness about the relevance of citizen science data, and fostering exchange and networking between decision-makers, project leaders and practitioners.

5 Communicating and disseminating knowledge and results

As a basic condition, policy makers and public servants need to be aware of citizen science, the opportunities it offers to help them achieve their policy priorities and goals, as well as how they can engage with citizen science. Benefits, needs, best practices etc. of citizen science for policy development need to be clearly and widely communicated. The combination of publications (e.g. policy briefs, guidelines), advocacy work, and face-to-face activities (e.g. stakeholder roundtables, discovery trips) can help introduce policy makers to the practices of citizen science. These documents and activities can help them see the relevance of these approaches and provide resources to convince their colleagues. Importantly, the terminology used may need to be adjusted to describe citizen science in a way that is relevant to policy makers.

Recommendations for awareness raising

The project EU-Citizen.Science offers recommendations for raising awareness among different audiences, such as policy makers., and a list of recommendations for boosting engagement of society, including policymakers, with citizen science, in both existing and new projects.

The WeObserve Impact Community of Practice members have developed the _Citizen Science Impact Storytelling Approach (CSISTA) to support Citizen Science initiatives and Citizen Observatories in capturing their success stories.

Case study - Noise Maps

NoiseMaps has had substantial political impact in terms of citizen empowerment, and enlarging political support for citizen science. The community in Raval, Barcelona, had problems with sound pollution. NoiseMaps empowered these citizens with skills such as open technology and know-how, in order to be able to collaborate with the city council. The relationship between the community and the city council was contentious, but the project was able to build bridges between them and change the attitude of both parties to one of collaboration.

By giving these citizens an evidence-based voice, they were able to contribute to policy agenda setting - reframing the problem of noise pollution. Through their work, NoiseMaps also increased general political support for citizen science. The city council has given positive feedback, and the project even became one of the official citizen science projects in the Citizen Science office of Barcelona. The project is a success story that spreads via public administration, and thus paves the way for better integration between citizen science and policy.

Case study - Wow Nature

The Wow Nature initiative supports the development of urban forests. It invited citizens and companies to plant or adopt an already existing tree, educating them about the benefits of trees in reducing CO2 concentration and the necessity to compensate for our emissions. The initiative is powered by Etifor, a spin-off of the University of Padua (Italy). Thanks to the pilot conducted within the ACTION acceleration, the team is now able to demonstrate the actual contribution of some of the urban forests they support in terms of air quality improvement and particulate matter (PM) abatement. This is providing them with more accurate data that will be used for their advocacy work, especially towards public administrations, so that more urban forests can be developed for making our cities greener and more sustainable.

Case study - Restart data workbench

The Restart Data Workbench project was specifically designed to create a dataset that would allow Restart to influence policy, to push for more sustainable products and the Right to Repair. As an organisation, they want to address the lack of data sources that represent the «real experiences of real people», and what happens with products used by normal people in all kinds of settings. This data can help to influence future regulation and tell a different story. What led Restart to work on this specific pilot was data about smart phone repairs, which helped them make the case in policy meetings at the EU level that manufacturers were not right in saying making screens and batteries available for repairs was sufficient. Restarts' data showed 3% of all repairs affected device cameras, and 2% speakers.

The data for their ACTION pilot was selected based on upcoming policy decisions about product regulations at EU level, which is a much bigger, and more flexible, process. Things and timelines keep changing in EU policy making, and individual policy processes are often sped up or slowed down. For example, Restart decided to begin with data on printers, but this did not end up being the next conversation for policy makers. Batteries as a topic also moved back and forth on the agenda, making it hard for the project to decide when to address which issue with citizen scientists, so the data would be ready in time.

Restart also carefully considers which of their data is most relevant to policy processes. For instance, they have high quality data about how old the products brought in for repairs are. This can tell an important story to policy makers, if it turns out that many people who are trying to repair products that are ten years old, while the current legislation is looking at up to five years. This data could then help to explain that this policy may be short-sighted.

Sustainability

As outlined above, projects have different approaches to the sustainability they want to achieve, which will depend on the goals they set themselves. A project may focus on a single question they want to answer, or conduct their research continuously. In the former case, once such a question is answered, more questions might follow, which could become part of the project; or the project could use their results to achieve impact, but otherwise conclude. Projects that conduct continuous research may evolve over time, and adapt their questions, data collection and processing. They will have to develop appropriate models to sustain both their community, and their finances.

With regards to sustainability, projects should consider three distinct aspects: Financial sustainability (i.e. continuous funding), output sustainability (i.e. keeping their results available for future use), and community sustainability. The community of a citizen science project are all the contributors who participate in it. It is important to support them to make it possible to maintain, or even to grow the project, and include a larger number of citizen scientists.

What measures a project takes towards sustainability can look very different, depending on their setup and goals. Sometimes a project may not need further funding or to consider long-term sustainability. Citicomplastic wanted to understand the compostability of bioplastics - a closed question, which they answered in the negative. Negative findings in research are not a bad thing: In this case, they implied that the composting of bioplastics would require involvement by policy makers, which the team attempted through engaging relevant stakeholders directly. Conversely, De Vlinderstichting is a continuous project, which has evolved over time. Beginning from counts of butterflies, they later added dragonflies, and adapted their processes from paper forms, through an online portal, to an app for participants. The team spends considerable efforts on maintaining their community, through regular events, newsletters, and other engagement opportunities. All this is enabled through their direct work with the Dutch government, who funds their work.

Long-term sustainability may also be achieved through building connections and ensuring the continued use of project outputs. The Water Sentinels project works with a group of fisherwomen to educate them about water quality research, and thus enabling their community to advocate for themselves. Similarly, rather than expanding their own project, Open Soil Atlas have teamed up with similar communities in other cities, who want to replicate their effort. All citizen science projects should consider which sustainability measures are appropriate for them.

Community sustainability

Citizen science projects rely on contributions from volunteers, many of whom contribute sporadically or for only short periods of time. This means that attracting and maintaining the interest of a large number of volunteers is crucial to the success of a project. At the same time, it is important to note that many projects are at their most popular and attract the largest number of participants when first starting out. As time passes and volunteers leave the project, it becomes increasingly important to attract and recruit new volunteers. The question of community sustainability, then, is crucial.

Before considering community sustainability, however, it is important to consider three questions:

- How much data does the project need?
- How quickly is that data needed?
- How many volunteers are required to ensure all data can be gathered within that time-frame?

Volunteer turnover is an inevitable part of any citizen science project. Many volunteers will potentially contribute very little to a project before they leave. It is therefore essential to address this by recruiting many participants throughout the project life-span.

Finally, and perhaps most importantly, projects only need to sustain their community for as long as they need this community. If a project is only intended to gather data to address a specific question, then when it has enough data, there is little need to sustain that community further. On the other hand, if it wishes to educate participants or carry out further research, then it should make sure that it is encouraging long-term participation, and that participants are aware of further opportunities to contribute and learn. If a project is part of a long-term goal, then it should recruit accordingly grow the project early and frequently and maintain the participants' interest. If a project is only short-term and can gather data quickly, then there may be less need for further recruitment, and it should consider only maintaining the initial community for long enough to complete those goals.

Financial sustainability

The majority of citizen science projects start out with financial support from small grants, mainly from public bodies, or are dependent upon goodwill, volunteering and pro bono work. However, these may not be sustainable, and financial sustainability is important for citizen science projects to run long term.

While costs at the beginning of a project may appear limited, projects should not underestimate the long-term requirements. Common costs projects need to cover include the purchase of hardware, such as sensors; communications costs; development or subscription fees for applications; staff costs, if not purely volunteer based; and infrastructure costs, for example to continue to run a website or database.

Becoming financially sustainable can be challenging for citizen science projects and for organisations that promote them. Depending on the project, there are various opportunities to ensure further funding or development of a business model to support a project. Care should be taken to ensure fairness in the commercialisation of any project that has relied on volunteer resources to develop. In practice, creativity is key to leveraging available opportunities. While the majority of environmentally focussed European citizen science projects rely on grant funding at initiation (Turbé *et al*., 2019), many projects rely on a portfolio of income streams and dynamic use of resources to maintain themselves (Cunha *et al*., 2017).

Hardware sales

Where hardware has been developed within a project, even if designs or data are made open access, sales of kits or pre-built hardware can contribute to a project's sustainability. Often this takes the form of consultancy on kit adaptation or improvement, training and similar.

Subscription models

Often going hand-in-hand with Hardware Sales, citizen science projects, such as the Air Quality Egg, have developed subscription models to unlock software as a service, for instance providing access to App features or data processing tools. These models rely, however, on having some non-open code or data, requiring careful navigation in relation to the data guidelines discussed above.

Crowd-funding

Crowdfunding platforms have gained popularity in funding citizen science projects since the early 2000s. Now used by both academic institutions and for bottom-up citizen science projects to gain funding, successful projects have a clearly defined goal and offer unique opportunities to their funders. Design and promotion of a crowdfunding campaign requires time and thought, and for content to be tailored to a particular audience. While a single crowdfunding instance does not deliver financial sustainability for a project – and can risk a high administrative overhead – this option can form part of a portfolio approach to maintaining a project long-term.

Up-scaling funding applications

Once a project has been running for a little while, generated results and demonsted impact, there is a stronger case to be made in applying for larger funding opportunities at a national and international level. Key factors that affect the strength of a follow-up funding case are: proven impact, strong dissemination, strong network (including international partner organisations if appropriate) and a strong argument for growing the project (either in terms of size, geographical reach, extending the approach to a new problem space...)

Direct donations

Projects with a strong cause-oriented or community dimension may be able to raise funds through direct donations. In this case, and in particular if running a donation drive, it is good practice to make the possibility of donating clear in publications (press releases, website, social media), and to put technological solutions in place to facilitate a smooth process of enacting the donation, such as a paypal donate button on the projects' web page. Communication materials should focus on the impact of the project on the key topic of interest of the community.

Reframing as science education

In strategies similar to those employed by science, citizen science projects can access new funding opportunities by (re-)framing their work as informal science education (Ottinger, 2017). This opens another stream of local, national and international funding and asks citizen science managers to streamline their approach in order to be scalable and applicable to different learning communities and settings. This approach may be particularly suitable for educational projects.

Private funding within the Corporate Social Responsibility framework

Large and medium sized enterprises support, as part of their Corporate Social Responsibility (CSR) plans, local initiatives that tackle topics close to the company focus or that are of special relevance for their managers and employees. This can be another channel for obtaining financial support for specific citizen science projects. In order to be successful when following this sustainability path it is important to get in touch with the potential funders directly by contacting the CSR manager with a short and to the point message that describes the project and its positive impacts. The selection of the companies to be contacted should be based mainly on two criteria: location and closeness to the projects' topic. In other terms, companies are interested in local impacts and prefer to support initiatives that have operated in the territory they operate with. At the same time, they tend to prefer initiatives that are somehow related to the topic or sector they operate in. For example, a sportswear company can be interested in citizen science projects that engage volunteers in outdoor measurement activities in nature. This potential stream of funding is more easy to pursue for projects that can count on a large community of volunteers and that can assure a good visibility to the funder.

Guidelines for financial sustainability

Community Funded guidelines

Community Funded is a crowdsourcing platform supporting research and non-profits. Both the platform and their guidelines can be useful for citizen science projects considering funding their projects through community contributions.

Crowdfunding platforms

Popular platforms for citizen science projects are kickstarter.com and indiegogo, Goteo and experiment.com. The latter was specifically designed for science projects, and vets the projects for minimum scientific rigour before publication.

ACTION Webinar on financial sustainability

In this webinar, supported by several experts, we present different complementary paths towards sustainability, including many discussed above, and practical examples.

Case study - Stara4all

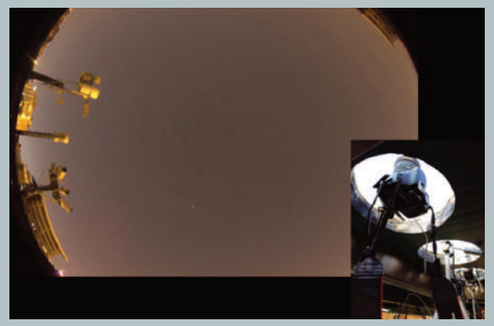
Stars4all was a project dedicated to light pollution, funded by the European Commissions' seventh framework programme. In order to assure sustainability of the project and its community, a not-for-profit, public interest foundation was established in Spain. The selection of this legal entity was driven by several considerations, such as the options to collect donations from private citizens and organisations, and to participate in public open calls. The Stars4all foundation sells photometers: a device developed during the initial project, which allows citizens to measure light pollution. The foundation is responsible for the manufacturing, sales and post-sale support. It has a marketplace where people can buy merchandise, and provides open data management support. It also supports CS projects in carrying out crowdfunding campaigns, and organises awareness raising events.

SUPPLEMENTARY MATERIAL

The ACTION pilots

AZOTEA

Azotea measures light pollution through photographs of the night sky. The brightness of the night sky and its color depend on the amount, type and location of light pollution sources, such as traffic, shops and offices. A decrease in human activity is normally associated with darker skies. AZOTEA monitors the brightness and color of the night sky using DSLR cameras on participants' roofs, to evaluate variations in light pollution during the global pandemic.



CITICOMPLASTIC

Citicomplastic co-created solutions for bioplastic waste management with vulnerable groups and other community members in Oslo (Norway). It set up a physical composting station for experiments, to raise awareness about bioplastic waste and how to handle it, demystify the science of composting, and narrow the distance between people and their trash.

DRAGONFLY AND PESTICIDES

This project is concerned with the effect of pesticides on dragonfly populations. Water quality has improved quite a lot in the second half of the last century and dragonflies, as aquatic insects, have recovered in this period. However recently numbers have started to decline again. Organiser *De Vlinderstichting* knows this because hundreds of their volunteers count dragonflies every two weeks on fixed transects. By comparing the number of dragonflies that are counted they can see how different species are doing in different locations, and even some of the least critical species seem to be disappearing from certain parts of the Netherlands. Even at levels regularly found in ditches, a specific insecticide can have strong negative effects on damselflies. In this project, participants take water samples, and pesticide concentrations are measured in a central laboratory. This allows the project to investigate whether the trends in dragonflies reflect the exposure to pesticides, the extent pesticides are a threat to dragonflies, and which pesticides are most harmful.

IN MY BACKYARD

This project aimed to understand, map, and ultimately reduce the use of pesticides and fertilisers, and encourage sustainable alternative practices in the context of home farming and gardening. Based in the Neiva river mouth area, in the municipality of Esposende, Portugal, it worked with a community of home farmers and gardeners. The project generated open data on pesticide and fertiliser usage in home production (farming and gardening) and sustainable practices for home farming and gardening.

LOSS OF THE NIGHT

This project invites citizen scientists worldwide to measure light pollution by using the human visual system as a light meter. Participants look for specific stars, and report if they can see them from their location through the Loss of the Night App. Measurements can be made wherever the sky is observable, for example in parks or in open spaces. Observations are sent anonymously to the Globe at Night project to be archived.

The illumination of the night sky increases annually, outshining the stars, indicating energy waste, and disturbing sensitive nocturnal species. Scientists are concerned that light pollution might have a big impact on nocturnal ecosystems, but they have very little information on how skyglow is changing, especially considering the recent transition to LED lighting. This cannot be achieved with current satellites, and in general is difficult to do via remote sensing, because satellites look at the ground, not towards the sky.

MAPPING MOBILITY

This is an online project, which teaches citizens how to collect spatially referenced mobility data about their travel patterns within their local community. Participants will use the data they collect to encourage and educate their community and local authorities about sustainable travel opportunities and barriers for the town, thus tackling issues of local transport-related pollution.

NOISE MAPS

This project allows citizens to generate and analyse urban sound data, empowering communities to take action to reduce unwanted noise and protect the local sonic heritage. The pilot builds on existing cultural practices of collective documentation of the sound heritage of neighbourhoods (Mapa Sonor). Thanks to project activities citizens will be able to filter unwanted noise out from authentic, locally unique sounds, thus allowing communities to take action to preserve their sonic heritage. NOISE MAPS deploys a combination of tested tech and methods with a novel approach, to empower communities to leverage the power of citizen science to tackle local challenges of global relevance.

OPEN SOIL ATLAS

This project is developing an open-source co-learning centre for a local community in Berlin. The centre will consist of a website presenting guidelines in a textual and infographic form to educate the public and raise awareness about soil quality and fertility, and the correlation between healthy soil and healthy communities. Participants learn how to make observations, test soil, interpret results and draw conclusions. Soil quality data and GPS locations are collected and will contribute to a high-resolution soil quality map. The process will then be replicated and expanded, in order to engage different communities and spread the analysis to new and different sites all over the world.

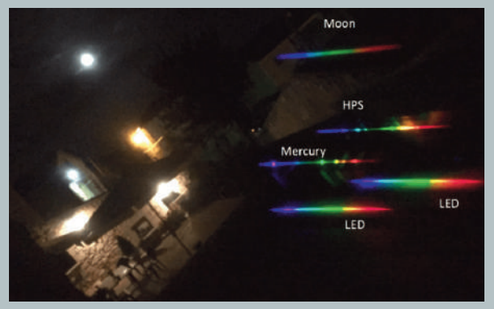
RESTART DATA WORKBENCH

This is an online project which addresses the global dimensions of pollution and consumerism, and the impacts of the take-make-throw economy. It explores together with the repair community what impact repairs of electronic devices have on the environment, especially our carbon footprint. The project will engage the wider public by creating online microtasks to analyse data about attempted repairs, investigating the environmental impacts of the products repaired and using our results to influence policy discussions.

SONIC KAYAKS

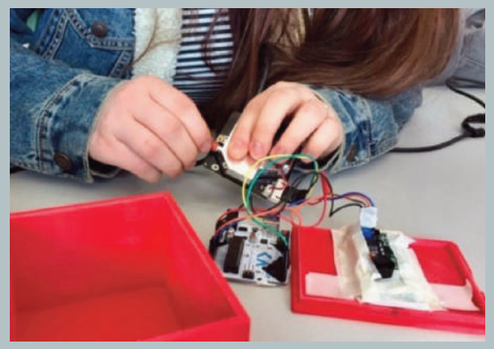
This project has been developing low cost open hardware for gathering and mapping fine-scale marine environmental data, which has not been previously possible to obtain. Data is sonified through an onboard speaker allowing paddlers to seek out areas of interest and gain real time feedback of the data. The existing system includes underwater temperature sensors and a hydrophone for measuring underwater sound, each recording data every second with GPS, time and date. Working with ACTION, two new environmental sensors (turbidity and air quality) were designed and integrated.

STREET SPECTRA



This project is mapping and characterising public lighting. Volunteers use a low cost diffraction grating on top of their smartphones' camera to take pictures of street lamps and their emission spectra. The resulting images allow classification of the street lamps by comparison with example pictures of well known lighting systems.
The creation of the project was motivated by the global switch to LED street lighting. The project creates a public database which is considered the primary output, and will allow scientists to study the effects of this change of technology on light pollution. Street Spectra is currently using epicollect5 to gather data, but an ad hoc mobile application is being developed to improve the participants' experience.

STUDENTS, AIR POLLUTION AND DIY SENSING



This is an educational project based in Norway, engaging high school students with the design and execution of their own air quality projects, using an off-the-shelf air quality sensor. The aim is to create awareness of sources of air pollution, make students think of ways to reduce emission and exposure, and teach them scientific methods.
The project offers a workshop for teachers where they get information about air quality and air pollution sources, measurements and (health) effects, as well as an opportunity to build a sensor themselves and learn how to program it, enabling them to teach it to their students. The students learn about air quality/air pollution and its effects on society, build their sensor packages and program them, carry out their own measurements, and interpret the results. At the end, all students are invited to join a student conference where they present their work on a scientific poster.

TATORT STREETLIGHT

This project is engaging citizen scientists in the protection of the insect fauna from light pollution. Street lighting can greatly affect nocturnal insects by attracting them to the light and depriving them of their habitats. In addition, if the attraction radii of adjacent street lights overlap, this can result in a barrier effect, making it much more difficult for insects to pass an illuminated street. For this reason, a new street lighting design will be developed to minimise the radiation of light onto the insect habitat. The geometry of the light is strictly directed downwards, so that the light only illuminates the sidewalks or streets and objects on it. The new street lighting will be installed in four communities in Germany. Tatort Streetlight observes the occurrence and behaviour of insects for two years before and after the conversion from the existing street light to the new design.
The project will collect insects from traps placed at street lights, and invite amateur entomologists to sample and identify insects, to discuss the results, and to develop ideas for sustainable solutions for night time illumination. For school classes, it will provide opportunities to work with insects, learn about the importance of insect diversity for many ecosystems, and learn about technological equipment to measure the impact of night time illumination.

WALK UP ANIENE

This project is based in the Aniene Valley Nature Reserve's in Rome's North East periphery. It engages visitors of the reserve with individual observation and data gathering activities using their phones, to collect key data about the area, map environmental criticalities, and support responsible institutions to plan environmental restoration. The project analyses the environmental quality of the river riparial area while enhancing participation at local level. Monitoring activities will provide data to develop a report on the Nature Reserve of the Aniene Valley and a GIS map that will highlight areas of main criticalities to be addressed, restoration needs and valuable areas to be protected.

WATER SENTINELS

This is an educational project that empowers people from coastal communities to serve as citizen scientists for water quality, and detect historical and current pollution events. Its goal is the conservation and restoration of seagrass meadows in the Sado Estuary area (Portugal). The project engages relevant stakeholders in data collection, and a water quality workshop. A community guide for water quality assessment, a layman's report and a video will be produced as tools to enhance engagement and participation of other community members on water quality assessment.

WOWNATURE

This project is based in the Po Valley in Northern Italy, which has one of the worst air qualities in Europe. It uses trees to tackle this problem: studies all over the world are demonstrating the ability of trees in capturing pollution particles, but evidence is needed at the local level. The project aims to measure air pollution with innovative sensors within and outside urban forests in order to assess their efficacy as a mitigation measure for air pollution, facilitate their funding and educate and engage with citizens. Citizens will be involved throughout the project, participating in data collection and in co-developing solutions and policies proposals. Project activities will include education and dissemination activities as well.

ABOUT THE ACTION PROCESS

Open calls

ACTION used cascading funding: A technique to redistribute funding to third party organisations who would be unable to apply for it at its source (in this case, the European Commission). Our pilots were mostly hosted by NGOs, but also other kinds of institutions, such as universities.

Our open calls - the way we allocated the cascading funding - followed this structure:

1. Preparation: At the start, the requirements of the call were identified, call documentation (such as applicant guides and application forms) prepared, and an application submission system set up. The call outline and selection criteria are based on the goals and details described in the projects' Grant Agreement - and therefore the source of our own funding.
2. Call: Running the call is an intense period of 2-3 months in which applications are written and submitted, and applicants are supported, e.g. through webinars or email.
3. Evaluation: Once the call closes, applications are screened for eligibility, and eligible applications reviewed by experts. Our review panel scored all applications, and a shortlist for interviews was drawn up based on these evaluations. A final selection was made by the consortium following the interviews.
4. Negotiation: Each selected applicant was allocated a mentor, who supported them henceforth. They all created a work plan and budget outline for the duration of the six month programme, and finally signed a contract to formalise their participation in the programme.

An indicative timeline from the second open call run in the ACTION project in 2020 is provided in Fig 1. below.

Fig. 1: Process overview of the second ACTION open call in 2020

The ACTION accelerator

Once successful applicants had been selected and their work programme agreed, they joined the ACTION accelerator. The ACTION accelerator methodology was developed in response to working closely with ACTION's citizen science projects, both those recruited through an open call, and with case study projects who were with the project from the beginning. Through the Accelerator, the adoption of best practice in participatory research has been refined and promoted.

The Accelerator provided citizen science projects with an intensive support programme, including mentorship, access to expertise, bespoke consultancy and training in engagement, data science, inclusion and participation. In addition the projects became part of a network of practice in participatory research, and participated in peer-to-peer learning.

Projects joining each round of the Accelerator were introduced to each other, their mentors, the ACTION project and consortium through an initial "Kick-off meeting", during which the participatory science lifecycle was introduced, along with the key focus areas of ACTION's research and knowledge-base. The Kick-off meeting was in each instance designed to match the needs of the incoming projects with best practice and the knowledge and expertise of the ACTION project. The projects agreed plans for the following six months of Acceleration with their mentors at the start of the Accelerator, including the KPIs and milestones by which the projects' progress would be measured. During the Accelerator period, projects participated in regular check-ins (usually once a month) alongside the offering of webinar training and regular calls to discuss diversity and inclusion. The Accelerator period closed with a final review of the projects' outcomes. More information on the Accelerator can be found in ACTION Deliverables: Final Reviews of the Calls (Austen 2020a, Austen 2021) and Workshop Reports (Austen 2020b and Austen 2022).

GLOSSARY

Term	Definition
Bottom-up	Refers to a situation where community members generate the research question or initiate a project. Opposite of >Top-down
Campaign	Short term activity or project
Collective Intelligence	Shared or group intelligence that emerges from the collaboration, collective efforts, and competition of many individuals and appears in consensus decision-making
Data cleaning	The process of removing inconsistencies from data (or dealing with outliers) before analysis
Data management plan	Document that describes the data lifecycle: how it is collected, processed, published, etc.
Data quality	Activities that apply quality management techniques to data, such as planning, implementation, or control, in order to assure the data is fit for consumption and meet the needs of data consumers
Data set	Collection of information belonging together (often a spreadsheet with values)
EDI	Equity, Diversity and Inclusion. This refers to the social dimension of citizen science projects
Experiment	Procedure carried out to test a hypothesis
FAIR principles	Principles that apply to open science data. The four principles are: Findability, Accessibility, Interoperability, and Reusability
GDPR	General Data Protection Regulation 2016/679. EU law governing data protection principles, including the collection, storage and usage of personal data
Hypothesis	Verifiable or falsifiable statement of an expected research outcome
Impact	Consequences of an action. For CS projects, impact primarily concerns intended consequences or goals
Intellectual Property Rights (IPR)	Rights of content producers. IPR are created with the development of any outputs (analysis, reports, videos, photos...). The most common form is Copyright. IPR can be sold, released, or adapted through > Licensing.
Licensing	Licenses regulate the ownership and legal use of resources, such as data. The most common form of licensing is Creative Commons. Licenses allow others to use the licensed resource under the terms the license defines (such as 'name the source')
Milestone	Key points in a project plan, that need to be achieved.
Motivation	Personal motivation is a key aspect in volunteers' participation in citizen science
Open Data	Data/information that is reusable by others through appropriate > Licencing
Platform	Software infrastructure that allows or eases specific steps of a citizen science project, such as data gathering (e.g. on EpicollectV,) or classification (e.g. on Zooniverse)
Policy maker	Any actor involved in making or influencing policy, at any level of government or another organisation
Research question	A question that a study or research project aims to answer. It often addresses an issue or a problem, which, through analysis and interpretation of data, is answered in the study's conclusion
Results aggregation	The process of grouping together results produced by multiple contributors.
Responsible Research and Innovation (RRI)	Approach to research and innovation that accounts for its > Impact
Sample	A specimen or small amount of something, often for analysis
Sensor	Device that measures something, often automatically
Stakeholder	All people/groups with an influence on or an interest in a project
Top-down	Refers to a situation where a person or institution outside the community, usually with authority within the research or governance space, initiates a project
Volunteers	Citizen science contributors participating in > Campaigns as volunteers

REFERENCES

Aristeidou, M., Scanlon, E., & Sharples, M. (2017). Profiles of engagement in online communities of citizen science participation. *Computers in Human Behavior*, 74, 246–256. https://doi.org/10.1016/j.chb.2017.04.044

Austen, K, (2020a), ACTION Final Report First Round of the Call: Lessons Learned from Running a Citizen Science Accelerator* *during a Pandemic https://doi.org/10.5281/zenodo.4533681

Austen, K. (2020b), ACTION Workshop Report 1 https://doi.org/10.5281/zenodo.5554639

Austen, K, (2021), Accelerating Citizen Science projects: Lessons from the Second Run https://doi.org/10.5281/zenodo.5638907

Austen, K. (2022), ACTION Workshop Report 2: Practical Steps to Supporting Best Practice in Citizen Science https://doi.org/10.5281/zenodo.5841614

Bandura, A. (1978). Reflections on self-efficacy. *Advances in Behaviour Research and Therapy*, 1(4), 237–269. https://doi.org/10.1016/0146-6402(78)90012-7

Baroni, I., Celino, I., González Guardia, E.(2022), Final guidelines, recommendations and tools for quality assurance

Bio Innovation Service, Directorate-General for Environment (European Commission), Fundación Ibercivis, & The Natural History Museum. (2018). Citizen science for environmental policy: Development of an EU wide inventory and analysis of selected practices. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/961304

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience*, 59(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Cunha, D. G. F., Marques, J. F., Resende, J. C. D., Falco, P. B. D., Souza, C. M. D., & Loiselle, S. A. (2017). Citizen science participation in research in the environmental sciences: Key factors related to projects' success and longevity. *Anais Da Academia Brasileira De Ciencias*, 89(3 Suppl), 2229–2245. https://doi.org/10.1590/0001-3765201720160548

Davis, L. F., Ramírez-Andreotta, M. D., & Buxner, S. R. (2020). Engaging Diverse Citizen Scientists for Environmental Health: Recommendations from Participants and Promotoras. *Citizen Science: Theory and Practice*, 5(1), 7. https://doi.org/10.5334/cstp.253

European Commission. (2014). Green Paper on Citizen Science. Citizen Science for Europe. https://ec.europa.eu/digital-single-market/en/news/green-paper-citizen-science-europe-towards-society-empowered-citizens-and-enhanced-research

Eveleigh, A., Jennett, C., Blandford, A., Brohan, P., & Cox, A. L. (2014). Designing for dabblers and deterring drop-outs in citizen science. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2985–2994. https://doi.org/10.1145/2556288.2557262

Gneezy, U., & Rustichini, A. (2000). A Fine is a Price. *The Journal of Legal Studies*, 29(1), 1–17.

Goeschl, T., & Jürgens, O. (2012). Environmental quality and welfare effects of improving the reporting capability of citizen monitoring schemes. *Journal of Regulatory Economics*, 42(3), 264–286. https://doi.org/10.1007/s11149-012-9191-6

Göbel, C, Martin, VY and Ramirez-Andreotta, M. (2017). Stakeholder Analysis: International Citizen Science Stakeholder Analysis on Data Interoperability. Washington, DC: Woodrow Wilson International Centre for Scholars. Available at https://www.wilsoncenter.org/publication/international-citizen-science-stakeholder-analysis (last accessed 23rd June 2021)

Grossberndt, S.; Passani, A.; Di Lisio, G.; Janssen, A.; Castell, N. (2021) Transformative Potential and Learning Outcomes of Air Quality Citizen Science Projects in High Schools Using Low-Cost Sensors. *Atmosphere*, *12*, 736. https://doi.org/10.3390/atmos12060736

Guerrini, C. J., Majumder, M. A., Lewellyn, M. J., & McGuire, A. L. (2018). Citizen science, public policy. *Science*, 361(6398), 134–136. https://doi.org/10.1126/science.aar8379

Intemann, K. (2009). Why Diversity Matters: Understanding and Applying the Diversity Component of the National Science Foundation's Broader Impacts Criterion. *Social Epistemology*, 23(3–4), 249–266. https://doi.org/10.1080/02691720903364134

Land-Zandstra A., Agnello G., Gültekin Y.S. (2021) Participants in Citizen Science. In: Vohland K. et al. (eds) *The Science of Citizen Science*. Springer, Cham. https://doi.org/10.1007/978-3-030-58278-4_13

Lee, T. K., Crowston, K., Harandi, M., Østerlund, C., & Miller, G. (2018). Appealing to different motivations in a message to recruit citizen scientists: Results of a field experiment. *Journal of Science Communication*, 17(1), A02. https://doi.org/10.22323/2.17010202

Maddalena, E., Baroni, I., Janssen, A., Thuermer, G. (2022) Final analysis and guidelines of incentives and motivation within citizen science

Martin, D., Carpendale, S., Gupta, N., Hoßfeld, T., Naderi, B., Redi, J., Siahaan, E. and Wechsung, I. (2017). Understanding the crowd: Ethical and practical matters in the academic use of crowdsourcing. In *Evaluation in the crowd. crowdsourcing and human-centered experiments* (pp. 27-69). Springer, Cham.

McKiernan, E. C., Bourne, P. E., Brown, C. T., Buck, S., Kenall, A., Lin, J., McDougall, D., Nosek, B. A., Ram, K., Soderberg, C. K., Spies, J. R., Thaney, K., Updegrove, A., Woo, K. H., & Yarkoni, T. (2016). How open science helps researchers succeed. *ELife*, 5, e16800. https://doi.org/10.7554/eLife.16800_

Ottinger, G. (2017) 'Reconstructing or Reproducing? Scientific authority and modes of change in two traditions of citizen science', in Tyfield, D. (ed.) *The Routledge handbook of the political economy of science*. Abingdon, Oxon ; New York, NY: Routledge.

Palmer, A., Reynolds, S. J., Lane, J., Dickey, R., & Greenhough, B. (2020). Getting to grips with wildlife research by citizen scientists: What role for regulation? *People and Nature*, 3(1). https://doi.org/10.1002/pan3.10151

Page, S. E. (2014). Where diversity comes from and why it matters? *European Journal of Social Psychology*, 44(4), 267–279. https://doi.org/10.1002/ejsp.2016

Passani, Antonella, Annelli Janssen, & Katharina Hölscher. (2021). Impact assessment framework. Zenodo. https://doi.org/10.5281/zenodo.4432132

Phillips, T. B., Ballard, H. L., Lewenstein, B. V., & Bonney, R. (2019). Engagement in science through citizen science: Moving beyond data collection. *Science Education*, 103(3), 665–690. https://doi.org/10.1002/sce.21501

Polleri, M. (2019). Conflictual collaboration: Citizen science and the governance of radioactive contamination after the Fukushima nuclear disaster. *American Ethnologist*, 46(2), 214–226. https://doi.org/10.1111/amet.12763

Re Calegari, G:, Celino, I., Scrocca, M., González, E. & Zamorano, J. (2020). Participant motivation to engage in a citizen science campaign: The case of the TESS network. https://doi.org/10.5281/zenodo.4068333

Reeves, N., Celino, I., Re Calegari, G. (2021). D 5.6 - Initial analysis and guidelines of incentives and motivation within citizen science. https://doi.org/10.5281/zenodo.5553724

Reynolds, A., & Lewis, D. (2017, March 30). Teams Solve Problems Faster When They're More Cognitively Diverse. *Harvard Business Review*. https://hbr.org/2017/03/teams-solve-problems-faster-when-theyre-more-cognitively-diverse

Resnik, D. B. (2019). Citizen Scientists as Human Subjects: Ethical Issues. *Citizen Science: Theory and Practice*, 4(1), 11. https://doi.org/10.5334/cstp.150

Robinson, L. D., Cawthray, jade L., West, S. E., Bonn, A., & Ansine, J. (2018). Ten principles of citizen science. In *Citizen Science: Innovation in Open Science, Society and Policy*. UCL Press. https://doi.org/10.2307/j.ctv550cf2

Roman, D., Reeves, N., Gonzalez, E., Celino, I., Abd El Kader, S., Turk, P., Soylu, A., Corcho, O., Cedazo, R., Calegari, G., Scandolari, D., & Simperl, E. (2020). An analysis of pollution citizen science projects from the perspective of data science and open science. https://doi.org/10.13140/RG.2.2.29949.38886

Schrögel, P., & Kolleck, A. (2019). The Many Faces of Participation in Science: Science & Technology Studies, 32(2), 77–99. https://doi.org/10.23987/sts.59519

Segal, A., Gal, Y. (Kobi), Simpson, R. J., Victoria Homsy, V., Hartswood, M., Page, K. R., & Jirotka, M. (2015). Improving Productivity in Citizen Science through Controlled Intervention. *Proceedings of the 24th International Conference on World Wide Web*, 331–337. https://doi.org/10.1145/2740908.2743051

Simperl, E., Reeves, N., Phethean, C., Lynes, T., & Tinati, R. (2018). Is Virtual Citizen Science A Game? *ACM Transactions on Social Computing*, 1(2), 1–39. https://doi.org/10.1145/3209960

Schaefer, T., Kieslinger, B., & Fabian, C. M. (2020). Citizen-Based Air Quality Monitoring: The Impact on Individual Citizen Scientists and How to Leverage the Benefits to Affect Whole Regions. *Citizen Science: Theory and Practice*, 5(1), 6. https://doi.org/10.5334/cstp.245

Scrocca, M., Scandolari, D., Re Calegari, G., Baroni, I., & Celino, I. (2021). The Survey Ontology: Packaging Survey Research as Research Objects. *Proceedings of the 2nd Workshop on Data and Research Objects Management for Linked Open Science - co-located with ISWC 2021*, https://doi.org/10.4126/FRL01-006429412

Skarlatidou, A., Suškevičs, M., Göbel, C., Prüse, B., Tauginienė, L., Mascarenhas, A., Mazzonetto, M., Sheppard, A., Barrett, J., Haklay, M., Baruch, A., Moraitopoulou, E.-A., Austen, K., Baïz, I., Berditchevskaia, A., Berényi, E., Hoyte, S., Kleijssen, L., Kragh, G., Legris, M., Mansilla-Sanchez, A., Nold, C., Vitos, M. and Wyszomirski, P., (2019). The Value of Stakeholder Mapping to Enhance Co-Creation in Citizen Science Initiatives. *Citizen Science: Theory and Practice*, 4(1), p.24. DOI: http://doi.org/10.5334/cstp.226

Standing, S., & Standing, C. (2018). The ethical use of crowdsourcing. *Business Ethics: A European Review*, 27(1), 72-80.

Teacher, A. G. F., Griffiths, D. J., Hodgson, D. J., & Inger, R. (2013). Smartphones in ecology and evolution: A guide for the app-rehensive. *Ecology and Evolution*, 3(16), 5268–5278. https://doi.org/10.1002/ece3.888

Tinati, R., Luczak-Roesch, M., Simperl, E., & Hall, W. (2017). An investigation of player motivations in Eyewire, a gamified citizen science project. *Computers in Human Behavior*, 73, 527–540. https://doi.org/10.1016/j.chb.2016.12.074

Tinati, R., Van Kleek, M., Simperl, E., Luczak-Rösch, M., Simpson, R., & Shadbolt, N. (2015). Designing for Citizen Data Analysis: A Cross-Sectional Case Study of a Multi-Domain Citizen Science Platform. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 4069–4078. https://doi.org/10.1145/2702123.2702420

Turbé, A., Barba, J., Pelacho, M., Mugdal, S., Robinson, L. D., Serrano-Sanz, F., Sanz, F., Tsinaraki, C., Rubio, J.-M., & Schade, S. (2019). Understanding the Citizen Science Landscape for European Environmental Policy: An Assessment and Recommendations. *Citizen Science: Theory and Practice*, 4(1), 34. https://doi.org/10.5334/cstp.239

ACKNOWLEDGEMENT

We are grateful to our pilots and partners, the participants in the ACTION toolkit workshop, and everyone who submitted suggestions, for their contributions to this toolkit.

ABOUT THE AUTHORS

The toolkit was edited by Gefion Thuermer, Research Associate at King's College London. Gefion's research focuses on online participation, process design, HCI and socio-technical aspects of data: to enable inclusive engagement wherever people use technology to achieve goals together. She previously worked on the Data Pitch project, where she was responsible for producing reports about the key lessons learned from the experience of data sharing, most notably a toolkit for data sharing. She currently works on MediaFutures, and ACTION, where she oversees the development of toolkits for data innovation in media value chains, and citizen science respectively.

All ACTION partners have contributed to this toolkit.

Named contributors are listed with their organisations.

Cefriel Società Consortile a Responsabilità Limitata
Ilaria Baroni
Damiano Scandolari
Mario Scroccal

Dutch Butterfly Conservation (De Vlinderstichting)
Roy van Grunsven

Dutch Research Institute for Transitions
Annelli Janssen

King's College London
Eddy Maddalena
Neal Reeves
Elena Simperl

Leibniz-Institut für Gewässerökologie und Binnenfischerei
Kat Austen
Franz Hölker
Sybille Schroer

NILU-Norwegian Institute for Air Research
Sonja Grossberndt

SINTEF
Dumitru Roman

T6 Ecosystems s.r.l
Antonella Passani
Katja Firus

Universidad Complutense de Madrid
Rafael Gonzalez Fuentetaja

Universidad Politécnica de Madrid
Esteban González Guardia
Oscar Corcho


ACTION