EUTOPIA

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CITIZEN SCIENCE STARTER KIT

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Carina Veeckman (VUB),
Floor Keersmaekers (VUB),
Karel Verbrugge (VUB), Eline Livémont (VUB)

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VUB VRIJE UNIVERSITEIT BRUSSEL
CY CERGY PARIS UNIVERSITÉ
UNIVERSITAS GOTHOBURGENSIS 1891
Univerza v Ljubljani
upf. Universitat Pompeu Fabra Barcelona
WARWICK

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PREFACE

The 'citizen science starter kit' provides information to researchers who are new to citizen science and who are considering initiating a citizen science research (project), regardless of the scientific discipline. It is a how-to guide for beginners, a foundation course, with the most essential information to get started.

The starter kit consists of different modules:

- **Module I** – Start to learn about citizen science. This first module reflects upon the different terms and characteristics used to describe citizen science. The benefits of citizen science research are listed, and the diversity of the field is illustrated with case studies in all scientific branches and disciplines.

- **Module II** – Determine if citizen science is right for your research. Before you initiate a citizen science project, you should reflect on whether it is suitable for your research. This module provides some reflective questions as well as decision frameworks to figure out the suitability of a citizen science approach.

- **Module III** – Crucial design factors for successful citizen science: This last module presents crucial design factors for planning and developing your citizen science research (project).

THE OBJECTIVE OF THIS STARTER KIT

The citizen science starter kit has the objective of sharing information about what citizen science is (and what citizen science is not) through definitions, guidelines and tips & tricks. Furthermore, it aims to raise awareness about the opportunities of citizen science through providing key examples of citizen science projects. As such, the starter kit also encourages researchers to start with citizen science, and to consider the citizen science approach in (project) proposals. Lastly, the starter kit also supports reflection and creative thinking. Through the questions provided, researchers should be able to make critical design choices for running a citizen science research (project).

TARGET AUDIENCES

The 'citizen science starter kit' targets researchers who are not yet familiar with citizen science. Maybe you have already heard about citizen science, but you do not know exactly what it entails or how to start with it. Therefore, the citizen science starter kit is entry level, and does not require any previous knowledge or skills in citizen science.

The starter kit targets researchers in any research discipline. Anyone is able to apply the starter kit in their domain. To enable this, the starter kit highlights examples from various scientific branches.

ATTRIBUTION

The citizen science starter kit is a deliverable of the EUTOPIA TRAIN project, and the writing has been coordinated by the Vrije Universiteit Brussel. The first edition is published in June 2022, and regular updates will follow. We would like to thank all the contributors for their inputs.

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MODULE 1: START TO LEARN ABOUT CITIZEN SCIENCE

The first module of this training programme reflects on the different definitions of citizen science found in literature, as well as its main characteristics. To understand what citizen science is (not), practical examples are given.

Furthermore, the benefits of citizen science are listed, both for science and society. At the end of the module, the diversity of citizen science is described through practical case studies in various scientific branches and disciplines.

At the end of this module, you should be able to define the main characteristics of citizen science and have a basic understanding about what citizen science is (not).

1.1. WHAT IS CITIZEN SCIENCE?

Citizen science is often used as an umbrella term to describe a wide range of participatory activities. Citizen science is also known as community science, crowd science, civic science, crowdsourcing, volunteer monitoring, volunteered geographic information, etc. This makes it rather challenging for practitioners who are new to the field to understand what citizen science is about.

In the last decades we have witnessed a rapid growth of citizen science (projects) in all scientific branches and disciplines. Societal and technological changes have allowed citizens to contribute more to science. Furthermore, citizen science is also receiving increasing attention from policymakers who are launching specific programmes on the local, national and international levels.

The increased interest brought along several definitions, with different terms used to refer to citizen science activities. As such, there is not one single exhaustive definition of what citizen science is, nor a set of specific quality criteria[1].

THE RISE OF CITIZEN SCIENCE

Citizen science was mentioned in the literature for the first time in the 1990s by Rick Bonney (US, ornithologist) and Alan Irwin (UK, sociologist). Bonney's concept of citizen science is nowadays more relevant than Irwin's. In their study on Public Participation in Scientific Research (PPSR) in 2009[2], Bonney et al. described citizen science as an approach for cost-effective data collection and for building public science literacy. In this publication, the term citizen science is rarely used, and they referred to PPSR instead.

However, the term is nothing new in the history of scientific research. If we look at the history of modern science, you can also label the first amateur scientists as 'citizen scientists'. In the 18th century, they were performing research from their living rooms before any formal academic institution existed. For instance, in Germany in 1786, Caroline Herschel discovered comet 'Caroline', by studying the skies on her own[3].

If you would like to read more on the historical background of citizen science, you can access this MOOC, or this resource of the Citizen Science Track project.

1 https://www.academia.edu/40004431/The_problem_with_delineating_narrow_criteria_for_citizen_science
2 Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. Online submission.
3 Gijsel, L., Huyse, T., & Van Hoyweghen, I. (2019). Citizen science: Hoe burgers de wetenschap uitdagen. Uitgeverij Pelckmans.

In this training programme, and in accordance with the Flemish Knowledge Centre on Citizen Science in Flanders (abbreviated, Scivil), we use the following definition:

> "Citizen science involves scientific research conducted in whole or in part by non-scientists (citizens), often in collaboration with, or under the guidance of professional scientists."
>
> *(Cambridge English Dictionary)*[4]

Citizen science thus refers to research conducted (at least in part) by citizen scientists, citizens who contribute to research in their free time. Citizen scientists often - but not always - collaborate with, or are supervised by domain experts, academics or governments.

SCIVIL – BRINGING SCIENCE AND SOCIETY CLOSELY TOGETHER

Scivil is the knowledge centre for Citizen Science in Flanders. Scivil was founded with funding from the Flemish government (Department of Economy, Science and Innovation) in early 2019 to unite, support and inform scientists, citizens, policymakers and organisations about citizen science. Scivil provides workshops and lectures on citizen science and provides advice to current and future citizen science projects. They also develop guides and manuals and set up thematic working groups on citizen science.

More information: https://www.scivil.be/en

In an article by Muki Haklay[5], who is widely recognized for his work in citizen science, a list of definitions of citizen science is provided. Depending on the context, it seems the definitions of citizen science can differ slightly. Some of them have an instrumental focus, while other definitions are rather descriptive or have a normative focus.

This multiplicity of definitions should not be regarded negatively. It is important that differences are supported, and they are essential for the further development of citizen science. One single definition would risk a variety of activities being excluded, or that certain practices would not fit into the specific field of research any more.

SUMMARY

There is no single definition of citizen science. The main message is to use the definition that is best suited to your context and that it represents public participation in scientific research.

4 https://dictionary.cambridge.org/dictionary/english/citizen-science

5 Haklay, M. M., Dörler, D., Heigl, F., Manzoni, M., Hecker, S., & Vohland, K. (2021). What is citizen science? The challenges of definition. In: K. Vohland et al. (eds.), The Science of Citizen Science, 13. https://doi.org/10.1007/978-3-030-58278-4_2

1.1.1. ECSA characteristics and principles

Amongst the multiplicity of definitions, the European Citizen Science Association (ECSA) provides some guidance to practitioners with regard to fundamental principles which are expected of a good citizen science project. In 2015, the association published the "Ten principles of citizen science", which cover the commitments between project organisers and participants on handling of data, ethics and open science, level of engagement in science, etc. It is an often cited and used resource for defining and implementing citizen science projects.

10 PRINCIPLES OF CITIZEN SCIENCE[6]

1. **Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding.** Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.
2. **Citizen science projects have a genuine science outcome.** For example, answering a research question or informing conservation action, management decisions or environmental policy.
3. **Both the professional scientists and the citizen scientists benefit from taking part.** Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g. to address local, national and international issues, and through that, the potential to influence policy.
4. **Citizen scientists may, if they wish, participate in multiple stages of the scientific process.** This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.
5. **Citizen scientists receive feedback from the project.** For example, how their data are being used and what the research, policy or societal outcomes are.
6. **Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for.** However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science.
7. **Citizen science project data and meta-data are made publicly available and where possible, results are published in an open access format.** Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this.
8. **Citizen scientists are acknowledged in project results and publications.**
9. **Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.**
10. **The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.**

Out of a need to further address the ambiguity in the field, ECSA and partners of the EU-Citizen.Science project have set up a working group which developed a set of characteristics of citizen science (based on the principles). These characteristics describe the range of activities that can or cannot be included within a citizen science activity. They recommend reading their document in conjunction with the principles since the characteristics provide concrete demonstrations of some of the principles. To further explain what citizen science is (not), we clarify some additional aspects which often lead to a misunderstanding:

- Citizen science is not equal to **science communication**. In citizen science research, the public actively participates in the research and is no longer solely the target of science communication. The public is also actively engaged in the scientific process, whereby science communicators still ensure that the whole process and outcomes are communicated in an accessible way to the participants.

6 https://zenodo.org/record/5127534#.Yrxh1-xBzzK

- Citizen science is **not** equal to science **'about'** citizens but rather refers to scientific research undertaken **'with'** or **'by'** citizens. In some disciplines, such as the medical and social sciences, it is common that citizens themselves, their behaviours, challenges, needs, etc. are under examination. In these disciplines, it is possible that people who take part in such projects can be both subjects and participants at the same time .

- The term 'citizen scientist' does **not** refer to a **scientist** whose work is characterized by a sense of responsibility to serve the best interests of the wider community. This definition was used by the New Scientist magazine in 1979 but is nowadays rarely being used.

- Citizen science is **not** driven by commercial gain. If the main aim of the activity is driven by commercial gains, e.g. being paid for providing data, then it is not considered to be citizen science.

Further tips:

- **ECSA platform** https://ecsa.citizen-science.net/
- We recommend exploring the EU-Citizen.Science platform of the European Citizen Science Association (ECSA), where you can find an extensive database of resources about citizen science, as well as the latest projects and updates in the field:
  - **ECSA resources** https://eu-citizen.science/resources
  - **ECSA projects** https://eu-citizen.science/projects
- Research work on 'Characteristics of Citizen Science'.
- Links towards other trainings and handbook resources:
  - Michael Pocock, Daniel Chapman, Lucy Sheppard & Helen Roy, Choosing and Using Citizen Science. (Centre for Ecology & Hydrology, 2014)
  - Lisa Pettibone, Katrin Vohland et al., Citizen science for all. A guide for citizen science practitioners. (Buerger schaffen Wissen, 2016)
  - John Tweddle, Lucy Robinson, Michael Pocock & Helen Roy, Guide to Citizen Science. Developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK. (UK-EOF, 2012)

Share your thoughts and opinions - Time for reflection:

- One of the most popular citizen science projects in Flanders is Curieuzeneuzen ('Curious Noses'). With 20,000 participants, it was one of the largest projects organised on air quality. Are you able to demonstrate that this is indeed a citizen science activity by applying the ten principles to this case?

- Two important delineators in the discussion on what citizen science is (not), are the level of engagement within a project and a genuine research outcome. Based on these criteria, can you give an example of a project which is not defined as citizen science?

- Is this citizen science or not?

1) On FixMyStreet, citizens can report incidents in public space (trash, damaged sidewalks, broken traffic lights, etc.) to their city or town. Volunteers often upload photos and observations to an application or online platform. Is this citizen science or not?

2) The Town-City Monitor is a policy monitor that assesses the broad environment of a city or town using about 300 indicators or sets of figures. More than 100 of these come from a large-scale three-yearly citizen survey. In all 300 Flemish cities and towns, citizens are invited to fill in a questionnaire to evaluate how they experience living in their city or town. Is this citizen science or not?

3) Sarah is a social worker, in Lewistown, Montana, USA. Her work is emotionally demanding, and she has discovered that watching birds helps her maintain her wellbeing. As a person new to birding, she is using a bird observation recording app on her phone. The app allows her to maintain a checklist of the birds that she observes. Observations are shared as open data and contribute to ornithological research and environmental management. Is this citizen science or not?

7 Walls TA, Coria A, Forkus SR. Citizen Health Science: Foundations of a New Data Science Arena. Int J Popul Data Sci. 2019 Sep 26;4(1):1074. doi: 10.23889/ijpds.v4i1.1074. PMID: 32935026; PMCID: PMC7299478.

4) Stefano is studying at high school in Trento, Italy. During a visit to the local history museum, he spends time at an interactive exhibit that shows him the different mammal species in the area, which were photographed with camera traps. The exhibit encourages visitors to identify them, giving a score at the end. The exhibit was designed by the museum's experts, and the data from the different interactions is not stored or used beyond statistics on how long sessions last, and how many visitors have used it. Is this citizen science or not?

5) Ella is a web designer and interested in a healthy lifestyle and technology. She uses the TopFit smartwatch to collect her biodata throughout the day to monitor and reach personal health and fitness goals including exercise, sleep, weight and more. She also shares her data with the TopFit community and sometimes participates in TopFit challenges. She pays a subscription fee and receives notifications, personal data dashboards or tips. She often follows the advice and has changed her routines accordingly. Is this citizen science or not?

1.1.2. Terminology matters

Terminology matters[11]– the words that we use for what we observe or what we describe can matter greatly for people. Language is a sensitizing concept.

Therefore, it is recommended that you communicate about the main terminology used, in accordance with the objectives of your research. Explain why you opt for certain terms and discuss how someone feels affected by them. For instance, which terms are you using to describe the citizen science activities, and what do you call people involved in the research?

In this sense, this training programme opts for the term '*citizen scientists*' or '*citizens*' to refer to people who participate in a citizen science project. These may be individuals, groups of citizens, or networks and organisations. On the other hand, we refer to '*researchers*' as professional scientists who work in academia or in a research-performing organisation who coordinate or participate in a citizen science project as a stakeholder. Activities can also be organised by public bodies (e.g. cities or towns) and non-governmental organisations (e.g. charities).

The below figure of the article of Eitzel et al. (2017) illustrates the commonly used names to describe people who participate in citizen science. Every term is explained and interpreted in a different (negative) way:

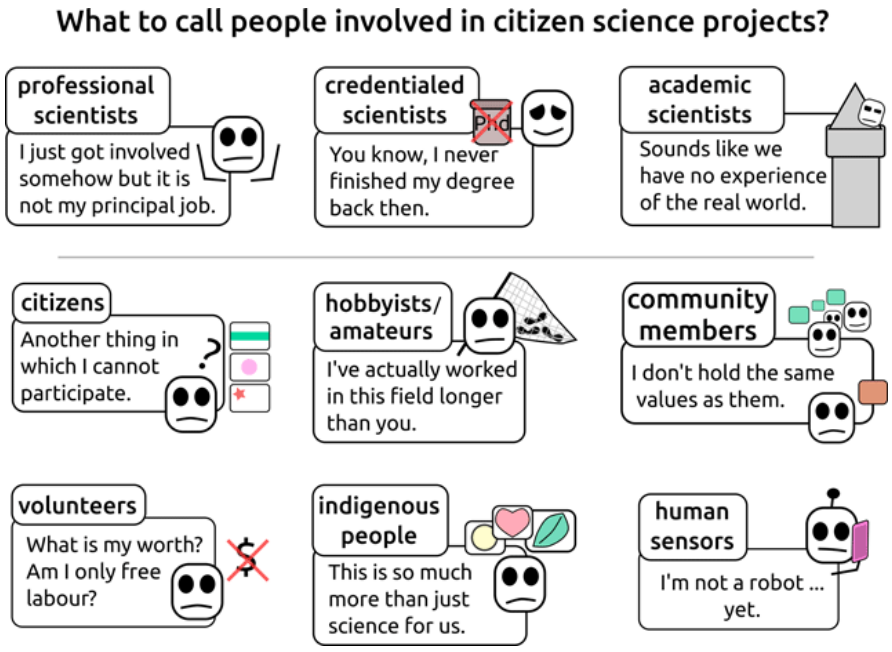


Figure 1 : What to call people involved in citizen science projects. Illustrated examples by Eitzel et al. (2017).

11 Eitzel, M.V., Cappadonna, J.L., Santos-Lang, C., Duerr, R.E., Virapongse, A., West, S.E., Kyba, C.C.M., Bowser, A., Cooper, C.B., Sforzi, A., Metcalfe, A.N., Harris, E.S., Thiel, M., Haklay, M., Ponciano, L., Roche, J., Ceccaroni, L., Shilling, F.M., Dörler, D., Heigl, F., Kiessling, T., Davis, B.Y. and Jiang, Q., 2017. Citizen Science Terminology Matters: Exploring Key Terms. Citizen Science: Theory and Practice, 2(1), p.1. DOI: http://doi.org/10.5334/cstp.96

SUMMARY

Think carefully about the terminology used in your citizen science research. You can explain the choice of wording and you can question your target audience to know how they feel affected by it. As such, you can determine the right terminology.

1.2. BENEFITS OF CITIZEN SCIENCE

Citizen science can yield a variety of benefits and outcomes. This chapter provides an overview of potential benefits, found in literature in a variety of scientific fields. These previous studies either investigated or observed specific benefits of involvement in citizen science.

Benefits can occur at an individual level or at the larger science-society interface. Benefits for scientists and citizens are mainly formulated as individual benefits, while societal benefits are formulated for society as a whole. From the individual participant's perspective, benefits can be related to, for instance, increased topical knowledge, while on societal level this can be related to political and environmental types of benefits.

	SCIENCE	SOCIETY
Individual level	Benefits for scientists	Benefits for citizen scientist
	E.g. increased research capacity	E.g. topical knowledge
Societal level	Science-society	Science-society
	E.g. more societally relevant research	E.g. impact on policies and institutions

Table 1: Benefits of citizen science at the individual and societal level.

It is important to note that this typology is not exhaustive and that benefits might be mutually inclusive. Furthermore, the types of benefits that can be generated will largely depend on the objectives and design of your research.

The main benefits for science and society are listed in detail in the following chapters, with additional reading tips.

1.2.1. Benefits for science

We start by listing benefits for science. Citizen science can yield individual benefits and outcomes for scientists in the following ways:

- I**ncreased research capacity:** One of the main reasons why scientists opt for citizen science is the increase in research capacity for data collection and analysis. The work done by citizens does not have to be performed by the researchers themselves, and this is particularly interesting when you want to set up a long-term monitoring programme with a large spatial and temporal coverage, or when a vast amount of data needs to be collected or analysed. The main advantage is thus the shared workload, up to the point where (some of) the research would not be able to take place without the tasks performed by the citizen scientists.

- **Newly acquired data and info:** Through the participation of citizens in your research, you can add lay, local and traditional knowledge to scientific knowledge. Citizen science can thus not only increase the amount of research data but can also result in more qualitative and diverse data and information that would otherwise have been very difficult to collect (e.g. in private gardens). You can gain access to localized knowledge (e.g. access to certain citizen communities), which might allow you to investigate a topic more deeply.

- **More innovative research:** By democratizing science processes and diversifying actors in the research, new research methods can arise, research strategies can be improved, and new discoveries can be made. This can lead to the production of new scientific knowledge and more innovative, or creative research.

On a broader societal level, citizen science can yield the following benefits:

- **More societally relevant research:** By including citizens in science, the research can account for citizens' needs. New research questions can be identified that otherwise would have been neglected. This can ensure that the research is more societally relevant and publicly accepted.

- **Bridging the gap between scientists and citizens:** Citizen science equals collaboration. When citizens are involved in science, mutual understanding can be created between citizens and scientists. Overall, this can develop mutual trust and confidence between scientists and the public.

- **Diversity in science:** When engaging with different actors (inter- or transdisciplinary), more diverse viewpoints and expertise can be included in the research process. This can lead towards more balanced points of view.

	BENEFITS FOR SCIENCE
Individual level (scientists)	• Increased research capacity • Newly acquired data and information • More innovative research
Societal level	• More societally relevant research • Bridging the gap between scientists and science • Diversity in science

Table 2: Summary of benefits for science (based on Goudeseune, et al. (2020)[13], Hecket et al., (2019)[14]

1.2.2. Benefits for society

Citizen science can also yield individual benefits and outcomes for citizens in the following ways:

- **Scientific literacy**: By participating in science activities, citizens can become more scientifically literate[15]. They gain insights into science in general, with the opportunity to learn specific skills and abilities (e.g. critical thinking skills, understanding basic analytical measurements, etc.).

- **Topical knowledge:** Being involved in citizen science activities can not only increase your knowledge about science, but also about the topic. Through training and experiential learning, citizen scientists may expand their knowledge of the issue central to the project. This is particularly the case when the project invests in educational efforts.

- **Behaviour change:** In turn, increased knowledge can lead towards changes in attitudes and behaviours. This is specifically the case for projects related to environmental topics, whereby an increased awareness and support for certain themes can occur (e.g. air quality, mobility, etc.). Furthermore, raised awareness is known to correlate with environmental stewardship. Citizens can hereby gain "a sense of ownership" for their natural environment and community. This can lead towards environmental activism, whereby citizens are empowered to be active stewards[16]. Alternatively, it can lead towards increased political participation or more healthy behaviours, depending on the topic of your research.

13 Goudeseune, L., Eggermont, H., Groom, Q., Le Roux, X., Paleco, C., Roy, H.E., van Noordwijk, C.G.E. (2020). BiodivERsA Citizen Science Toolkit For Biodiversity Scientists. BiodivERsA report, 44 pp.

14 Hecker, S, et al. 2019. How Does Policy Conceptualise Citizen Science? A Qualitative Content Analysis of International Policy Documents. Citizen Science: Theory and Practice, 4(1): 32, pp. 1–16. DOI: https://doi.org/10.5334/cstp.230

15 Queiruga-Dios, MÁ, López-Iñesta, E, Diez-Ojeda, M, Sáiz-Manzanares, MC, Vázquez Dorrío, JB. Citizen Science for Scientific Literacy and the Attainment of Sustainable Development Goals in Formal Education. Sustainability. 2020; 12(10):4283. https://doi.org/10.3390/su12104283

16 Jordan, R., Gray, S., Howe, D., Brooks, W., & Ehrenfeld, J. (2011). Knowledge gain and behavioral change in citizen-science programs. Conservation Biology, 25(6), 1148–1154. https://doi.org/10.1111/j.1523-1739.2011.01745.

On a broader societal level, citizen science can generate the following benefits on the political and environmental level:

- **Political benefits:** Firstly, the data collected in citizen science projects can help to inform, decide and follow up on policies, which can make them more societally relevant. Citizen science can provide an evidence base for data-driven policymaking. Furthermore, by involving citizens in decision-making processes, it can result in greater acceptance and support for important policy themes. The data gathered in citizen science can eventually also impact on policies and institutions.

- **Environmental benefits:** Citizen science projects can also lead towards improved environments or livelihoods, and often have a cross-over with the implementation of nature-based solutions. For instance, citizen science research can help to identify polluters or exotic threatened species, or can help to reinforce tougher environmental policies, laws or regulations with evidence-based data.

	BENEFITS FOR SCIENCE
Individual level (scientists)	• Scientific literacy • Topical knowledge • Behavioural change (including stewardship and civic participation)
Societal level	**Political benefits:** • Data-driven policymaking • Societal relevancy of policy • Impact on policies and institutions **Environmental benefits:** • Improved environments and livelihoods

Table 3: Categories of benefits (based on Den Broeder et al., 2016[17], Hecket et al., (2019)[18], Veeckman et al. (2021)[19], Walker et al. (2021)[20])

Further reading tips:

- To gain more insights into the outcomes of your project, you can set up a summative evaluation of the project's benefits for its participating citizens and society as a whole. For executing this type of evaluation, you can check the following online learning course of the Centre of Social Innovation on the eu-citizen.science platform.

- Understanding what citizens gain from engaging in citizen science can help in recruiting and retaining. This article matches motivational theories with benefits in citizen science.

- The Cornell Lab of Ornithology has developed different tools for measuring outcomes and evaluating citizen science projects. A specific toolkit is available for measuring citizen outcomes.

- The Impact Wizard, developed by 'Sociale Innovatie Fabriek', can also help to evaluate societal impact. It is based on change theories.

- Citizen science can yield many more advantages for citizens at the individual level, such as increased social capital[21], place-making[22] and self-efficacy[23].

17 Lea Den Broeder, Jeroen Devilee, Hans Van Oers, A Jantine Schuit, Annemarie Wagemakers, Citizen Science for public health, Health Promotion International, Volume 33, Issue 3, June 2018, Pages 505–514, https://doi.org/10.1093/heapro/daw086

18 Hecker, S, et al. 2019. How Does Policy Conceptualise Citizen Science? A Qualitative Content Analysis of International Policy Documents. Citizen Science: Theory and Practice, 4(1): 32, pp. 1–16. DOI: https://doi.org/10.5334/cstp.230

19 Veeckman, C., Van Herck, B., Carpentier, M., Van Laer, J. & Sterken, M., (2021). Citizen Science Roadmap for Local Government. A hands-on manual for citizen science, by and for cities and towns. SCIVIL, Leuven, Belgium.

20 Walker, D. W., Smigaj, M., & Tani, M. (2021). The benefits and negative impacts of citizen science applications to water as experienced by participants and communities. Wiley Interdisciplinary Reviews: Water, 8(1), e1488.

21 Butkevičiene, E., Skarlatidou, A., Balázs, B., Duží, B., Massetti, L., Tsampoulatidis, I., & Tauginienė, L (2021). Citizen Science Case Studies and Their Impacts on Social Innovation. In: K. Vohland et al. (eds.), The Science of Citizen Science, 309. https://doi.org/10.1007/978-3-030-58278-4_16

22 Toomey, A. H., Strehlau-Howay, L., Manzolillo, B., & Thomas, C. (2020). The place-making potential of citizen science: Creating social-ecological connections in an urbanized world. Landscape and Urban Planning, 200, 103824.

23 Resnik, D. B., Elliott, K. C., & Miller, A. K. (2015). A framework for addressing ethical issues in citizen science. Environmental Science & Policy, 54, 475-481.

1.3. THE CITIZEN SCIENCE LANDSCAPE

Citizen science projects can be organized within many scientific branches and disciplines. To showcase the diversity, this chapter describes citizen science practices in the natural sciences, formal sciences, medicine & health, arts & humanities, and the social sciences. Some scientific disciplines already have a long-standing tradition with citizen science, while others are just at the beginning.
Specific case studies are provided in each research field. At the end of the module, a list of additional sources is provided with inspiring examples of citizen science across Europe.

1.3.1. Citizen science in the natural sciences

The natural sciences combine the study of living and non-living systems, with specific disciplines in the physical sciences (e.g. chemistry, astronomy, etc.) and life sciences (e.g. zoology, environmental sciences, etc.). The history of the natural sciences is closely related to citizen science . Many amateur scientists have shaped and grounded the natural sciences by observing environmental phenomena and recording their findings. These amateur scientists outlined the beginnings of the professionalization of science. Through this development, the natural sciences are the most commonly practised scientific discipline in citizen science.

Furthermore, nowadays the natural sciences easily lend themselves to citizen science approaches through the usage of sensors and/or by organizing large-scale monitoring campaigns across space and time (cf. Module II). These monitoring projects mainly invite citizens to collect data by counting species such as counting birds or butterflies. The best-known examples of citizen science in Flanders perform(ed) in the natural sciences are focused on biodiversity, mobility and air quality.

The data collected in these citizen science projects can have a significant potential to support public authorities in policymaking. In support of this, the European Commission is advocating a more systematic integration of citizen science into environment-related policy (e.g. the European Green Deal and the United Nations Sustainable Development Goals). In this report you can read more about the opportunities and benefits of using citizen science for environmental monitoring, with good practices and obstacles for further uptake.

CASE STUDY ANIMALS IN THE WILD - LOOKING FOR TRACKS IN THE CITY

Green and open spaces play an important role in the quality of life in cities. With increasing population density in cities, these areas and thus the habitats for urban wildlife are increasingly coming under pressure. Through the project "StadtWildTiere" in Germany, Switzerland and Austria, residents from urban areas are asked to share observations via photographic material of animals or their tracks on an online platform. Volunteers can also rent a camera trap to make observations. StadtWildTiere works with ambassadors, where each ambassador is responsible for observations of one square kilometre of the city. The ambassadors are asked to take regular walks and to talk to residents of their area. A specific training to recognize animal tracks is offered by the institute StadtNatur. The data are used for scientific studies by a team of biologists and ecologists from the StadtNatur team. Read more about this project: https://stadtwildtiere.ch/

24 Frigerio, D., Richter, A., Per, E., Pruse, B., Vohland, K. (2021). Citizen Science in the Natural Sciences. In: K. Vohland et al. (eds.), The Science of Citizen Science, 79. https://doi.org/10.1007/978-3-030-58278-4_5

1.3.2. Citizen science in the formal sciences

In contrast to the natural sciences, the formal sciences do not have a long-standing tradition of collaborating with citizen scientists. Formal science is a branch of science studying disciplines concerned with formal systems such as logic, mathematics, computer science, artificial intelligence (AI), game theory, etc. The adoption of citizen science approaches into this field is just in its infancy, but it is expected that new technological developments, especially in the field of AI, will provide momentum.
For instance, examples of mathematical projects that have adopted aspects of citizen science can be found in collective problem solving and distributed computing[25]. The former projects are focusing on online collaboration between mathematicians who help to solve difficult mathematical problems (e.g. the Polymath project), while the latter projects engage citizens who offer their time and devices. Citizen scientists are requested to install and download a tool on their computer. The application monitors the computer for spare computing power and that power is used to solve a mathematical problem. This type of project does not involve the citizens on a personal level, as they only need to install a programme and donate their CPU time (e.g. The Great Internet Mersenne Prime Search).

The usage of AI in citizen science enables cross-over with other scientific disciplines, with citizen science applications using machine learning techniques for biodiversity monitoring for instance. AI is currently used in citizen science for assisting or replacing humans in completing tasks (e.g. classifying images for species detection), influencing human behaviour (e.g. through personalization and behavioural segmentation), and for improved insights (e.g. training of algorithms using citizen science data)[26]. It is likely that new applications of AI in citizen science will appear in the future.

CASE STUDY – EYE FOR DIABETES

Citizen scientists in the Eye For Diabetes project examine the retinal images of diabetes patients online via the Zooniverse platform. They note any signs of diabetic retinopathy, a disorder which can lead to blindness. The catalogue of images can then be used to teach an algorithm to recognise the disorder, paving the way for screening by artificial intelligence. As such, the citizen scientists are helping to build up a reference database of annotated images, which can be used to train an AI software to recognise diabetic retinopathy in future. This project clearly exemplifies the cross-over between the formal sciences and health research.
More information about this project: https://www.oogvoordiabetes.be

25 Hartkopf, A. M. (2019). Developments towards Mathematical Citizen Science. In Forum Citizen Science 2019.
26 Ceccaroni, L., Bibby, J., Roger, E., Flemons, P., Michael, K., Fagan, L. and Oliver, J.L., 2019. Opportunities and Risks for Citizen Science in the Age of Artificial Intelligence. Citizen Science: Theory and Practice, 4(1), p.29. DOI: http://doi.org/10.5334/cstp.241

1.3.3. Citizen science in medicine & health

Health science has lagged far behind in adopting a citizen-based approach, although the number of projects in this domain is increasing nowadays. This increased interest is fed by various trends, including increased education among the general population and the emergence of sensors and self-tracking devices[27]. Citizen science in health, or citizen health science, focuses on questions raised by citizens with varying levels of scientific participation with scientists. Often citizens collect data on their own health and act of their own accord to change outcomes.

The development of citizen health science involves certain challenges related to norms. Traditionally, health science and medicine have been in the hands of a few, while participatory science in health comes with shared initiation and leadership. Furthermore, there can be potential liabilities, such as inherent biases or issues with validity of the results. Despite these concerns, there is also a great potential for innovation. Citizen science in healthcare can ensure that the research is better tailored to what patients want, resulting in a higher probability of relevant scientific knowledge for a broader range of stakeholders.

If you are interested in citizen health science, there is an ECSA working group called 'Citizen Science 4 Health'. Its main objectives are to create a community of stakeholders on citizen science for health, to develop and disseminate tools, methods, ethical frameworks and training material, and to enhance the visibility and potential of citizen science in the health domain.

CASE STUDY: ISALA

Isala is a citizen science project that wants to get a better understanding of the female microbiome using state-of-the-art DNA technology. The project is organized by an interdisciplinary team of researchers at the University of Antwerp. In March 2020, a call was launched in Belgium to find 200 people willing to take a swab from their vaginas, skin and saliva. In total, more than 3,300 women reacted and received a testing kit. With the help of bioinformatics, researchers studied the genetic code of the bacteria. Results revealed that 80% of the participants had a vaginal microbiome dominated by lactic acid bacteria; these bacteria are associated with a healthy vagina. The participants received the outcomes of the study and are further invited for a second phase whereby the research data will be combined with extensive questionnaires to exert factors that impact the health of the vagina.

Read more about this project: https://isala.be/

27 Walls, T. A., Coria, A., & Forkus, S. R. (2019). Citizen Health Science: Foundations of a New Data Science Arena. International journal of population data science, 4(1), 1074. https://doi.org/10.23889/ijpds.v4i1.1074

1.3.4. Citizen science in the arts & humanities

Citizen science in the humanities, or citizen humanities, encompasses fields such as languages, literature, history, philosophy and art. The primary object of investigation is human culture, and it favours methods of interpretation, critical thinking and analysis[28]. Typologies in the citizen humanities have been proposed to classify the activities and range from on-site projects to digital-only projects, whereby citizens are invited to participate in data collection or data analysis of artefacts. These artefacts can be physical or digital, either collected or provided by archives, repositories, galleries or museums, or provided by the citizens themselves[29]. Citizens often perform tasks that include curating, transcribing, or annotating artefacts.

Many projects have been taking place in the arts and humanities, and are often coordinated by universities, museums and archives. In terms of science communication, museums and archives are increasingly incorporating experimental zones and labs, where volunteers can participate or contribute to exhibitions.

If you are interested in citizen science in the arts and humanities, you can have a further look at this training module. It helps you recognize and define approaches for incorporating citizen science into your research project.

CASE STUDY: ENRICH YOUR VIEW OF BRUGES

In the citizen science project 'Verrijk de kijk op Brugge' (Enrich your view of Bruges), participants help to describe images from the city archives, the public library and 'Musea Brugge'. Participants are asked to look at the images and describe what they see. Which people can you identify? What buildings do you recognize? Do you recognize Bruges or a borough? Participants complete an instructional form and then transmit the information to the registrars. The finalized information is shared through this website.

28 Heinisch, B., Oswald, K., Weißpflug, M., Shuttleworth, S., Belknap, G. (2021). Citizen Humanities. In: K. Vohland, et al. (eds.), The Science of Citizen Science, 97. https://doi.org/10.1007/978-3-030-58278-4_6

29 Heinisch, B., Oswald, K., Weißpflug, M., Shuttleworth, S., Belknap, G. (2021). Citizen Humanities. In: K. Vohland, et al. (eds.), The Science of Citizen Science, 97. https://doi.org/10.1007/978-3-030-58278-4_6

1.3.5. Citizen science in the social sciences

Citizen science in the social sciences, or citizen social science, has been developing in meaning and prevalence over the past decade. Broadly, we define citizen social science as an approach which involves participants in a social sciences research project[30], whereby they implement tasks which are traditionally implemented by scientists. These projects have a specific focus on social or behavioural aspects, or they take place within an interdisciplinary synergy (e.g. natural sciences and social sciences). A synergy with the social sciences helps to understand the human dimension in the study, enriches the scientific research and helps to boost public participation[31].

A crucial distinction should be made between citizen social science and the participation of volunteers in a research study by giving an interview, joining a focus group or responding to a survey. These latter are not referred to as citizen science since citizens are the research object and are not actively participating in the research process. Within citizen social science, participants enrich the research process by asking questions or choosing research methods that might not have occurred to professional scientists. Furthermore, they can make the research study more refreshing and inclusive by drawing on their social and cultural capital[32]. Citizen social scientists might have connections with relevant communities or places of interest, which professional scientists might not have considered or have access to.

If you are interested in citizen social science, the CoACT project is currently looking into participatory research forms which are directly driven by citizens and their social concerns.

CASE STUDY: HEALTH CONNECTS AMSTERDAM-SLOTERMEER

In 2014 and 2015, a group of Slotermeer residents attended a training to become Health Ambassadors. These residents interviewed their neighbours about how healthy they think Slotermeer is in terms of litter, exercise and sports, child-friendliness, greenery in the neighbourhood, ambience, traffic and transportation, etc. They collected this information from local residents and, in turn, gave them advice on certain topics, such as moisture problems at home. The ambassadors learned how to interview, gained additional knowledge, and started to think more positively about the health of Slotermeer. Moreover, the interviewers came into contact with people outside their direct network. This way, talking about health served a connecting function, crossing cultural differences. The results were presented during a health festival for local residents and other interested parties. They will also be used to complement existing scientific insights and to better align policy with practice. A total of 221 interviews were conducted by 22 ambassadors.

Read more about this project: http://www.kijkeengezondewijk.nl; https://www.rivm.nl/gezonde-leefomgeving/kijk-gezonde-wijk-watsap-project

30 Purdam, K. 2014. Citizen social science and citizen data? Methodological and ethical challenges for social research. Current Sociology, 62(3): 374–392. DOI: https://doi.org/10.1177/0011392114527997

31 Tauginienė, L., Butkevičienė, E., Vohland, K. et al. Citizen science in the social sciences and humanities: the power of interdisciplinarity. Palgrave Commun 6, 89 (2020). https://doi.org/10.1057/s41599-020-0471-y

32 Fischer, A., Dinnie, E., Ellis, R., Eastwood, A., Carter, A. and Welsh, G., 2021. Exploring the Potential of Citizen Social Science for Environmental and Sustainability Research: Experiences of and with Community-Based Researchers. *Citizen Science: Theory and Practice*, 6(1), p.17. DOI: http://doi.org/10.5334/cstp.389

1.3.6. More examples of citizen science

- Agilas (archaeology)
- Airbezen (air quality)
- CurieuzeNeuzen (air quality research 2018)
- CurieuzeNeuzen in de Tuin (garden research, heat stress)
- De Grote Schelpenteldag (biodiversity)
- D-Noses (measuring scents)
- DoeDat platform (various domains)
- InfluencAir (air quality)
- Luftdaten (air quality)
- MamaMito (genealogy & genetics)
- Mijn Tuinlab (garden research, health, biodiversity, sustainability)
- Paleontologica Belgica (palaeontology)
- Radio Meteor Zoo (meteorology)
- Researching Age-Friendly Cities (health and wellbeing)
- S.O.S. Antwerpen (social injustice in mortality)
- Straatpoëzie.nl (literature research)
- Straatvinken (traffic counts)
- Telraam (traffic counts)
- VeleHanden (heritage)
- Verrijk de kijk op Brugge (artistic research)
- Waarnemingen.be (nature observations)
- Waterland vzw (healthy rivers)

1.3.7. Other websites

The following websites may offer further inspiration on examples of citizen science in Belgium:

- http://www.iedereenwetenschapper.be/: This website lists citizen science projects in Belgium and the Netherlands. You can also advertise your project here to find citizens.

- Hoemeetiklucht.be: Here you can find information about measuring air quality through citizen science. There is an extensive list of possible sensors that you can use for specific parameters.

- https://www.scivil.be/projecten: This website lists citizen science projects funded by project calls of the Department of Economy, Science and Innovation in Flanders.

Other international examples:

- The Zooniverse platform lists projects in the sciences, humanities, and more (e.g. arts, biology, climate, language, literature, etc.). The Zooniverse is a collaboration between institutions from the United Kingdom and the United States.

- Inspiring examples of citizen science in Austria can be found here (German/English). This website is managed by the Citizen Science Network in Austria (CSNA). You can search by different domains (weather, mobility, culture, language, etc.) and by type of tasks.

- Citizen science in health care organized by ZonMw (independent health care research organization in the Netherlands).

- SciStarter is a popular US-based Citizen Science portal with more than 3,000 projects, searchable by location, topic, age level, etc. SciStarter hosts an active community of close to 100,000 registered citizen scientists and millions of additional site visitors. https://scistarter.org

MODULE 2: DETERMINE IF CITIZEN SCIENCE IS RIGHT FOR YOUR RESEARCH

Before you choose a citizen science approach, it is recommended that you reflect on whether it is the right method for your research (project). Citizen science does not fit for all research topics. In certain circumstances, more conventional science methods or other types of public engagement mechanisms might just do the trick or might be even better suited.

This module helps you to reflect and determine whether citizen science is the right method for your research (project). Several situations are described which lead to shared benefits in citizen science, with helpful examples in the various scientific disciplines.

At the end of the module, you should be able to make a profound decision concerning whether citizen science is suitable for your research (project) and be able to decide upon the type of citizen science research. The different types of citizen science approaches are explained at the end of the module.

2.1. WHEN IS A CITIZEN SCIENCE APPROACH APPROPRIATE?

Citizen science may yield many benefits, both scientifically and socially. However, when you are new to citizen science it is hard to decide whether it is the right approach for your research objectives. In the right circumstances, citizen science may be very beneficial. In other circumstances, it may be that other ways to engage the public are more suited.

In this chapter, several decision-making factors are described to help you decide whether citizen science is a viable option. Before you start your project, we advise you to reflect upon the following elements in order to make a well-founded decision:

Readiness level towards public engagement	The importance of engagement	Transdisciplinary research	The spatial and temporal scale
The amount of data that need to be analysed	The complexity of the protocol	Promotion of scientific learning	The available project budget

Table 4: Main elements for assessing the suitability of a citizen science approach.

2.1.1. Readiness level towards public engagement

Before you start, take a step back and reflect on the following question: *"What is your mindset towards public participation in scientific research, and do you have the capacities to organise it?"* It might be that you have an experience-based opinion, or that you are completely new to the topic.

Nowadays, there is a trend in academia to invest in public engagement mechanisms. More and more projects are getting support for not only opening up research results to society, but also for genuinely engaging the public in research projects. However, little research has been performed on understanding potential organisational shifts within academic culture regarding public engagement. What are the attitudes nowadays towards pursuing public engagement in the university, in specific departments and of individual researchers? Is it practically achievable, and which processes need to change for supporting it? Which capacities are needed, what are potential obstacles?

For conducting citizen science projects, we highlight the following questions to assess your readiness level:

- To what extent do you have an open attitude towards collaborating with citizens? Are you willing to listen to their ideas and actively use the information for your research?
- To what extent would you trust the information collected by citizens?
- To what extent are you open to sharing power and ownership over the scientific process and developing a mutual relationship between scientists and citizens?
- To what extent are you flexible to adapting the research process based on the collected findings?
- How do you feel about openly sharing your research data?
- To what extent can you be open and transparent about the scientific process?
- Do you have the necessary capacities to support public participation in research?

Applying citizen science might thus come with a change in working habits, operational processes, and in hierarchies. The extent of it is dependent on the type of citizen science project you are going to implement (cf. Section 2.2: Typologies of citizen science project). Furthermore, different challenges might be encountered than those in more conventional scientific methods. Specific obstacles regarding the design and organisation of the project might be experienced (e.g. the mobilisation of participants and sustaining engagement) but also data-related challenges (e.g. data quality)[33].

If the answers to these questions reveal that you need further support for applying a citizen science approach, then the Citizen Science Contact Point can help you. Look out for our various series of workshops and specific one-to-one support services. Module III also provides more concrete information related to data management and team capacities.

SUMMARY

Certain attitudes and new working practices come into place when practising citizen science. Before you consider citizen science, it is advised that you self-reflect on your readiness level. To what extent can you be transparent, open and deliberative about your research? Which capacities are needed to perform the research? You are welcome to contact the Citizen Science Contact Point if you need further support on this.

Reading tips:

- This literature review by Weingart et al. describes the main trends on public engagement, and how it shifted from 'public understanding of science' to 'public engagement with science'.

- Have you already heard about the term 'RRI'? RRI, or Responsible Research and Innovation, is a policy-driven discourse that emerged from the European Commission. It aims to foster the design of inclusive and sustainable research and innovation, with an emphasis on co-creation. If you would like to learn more about this discourse, you can read this handbook.

33 European Commission (2020). Best Practices in Citizen Science for Environmental Monitoring. COMMISSION STAFF WORKING DOCUMENT SWD (2020) 149 final; p. 76.

- The Eurobarometer of May 2021 questioned citizens' opinions on inclusion in science and technology. The study revealed that six out of ten think that involving non-scientists in research ensures that science and technology will better respond to the needs, values and expectations of society.

- Citizen science is one of the eight ambitions of the EU's Open Science policy. The aim is to engage and involve citizens and civil society organisations in co-design and co-creation processes so as to promote responsible research and innovation.

- Read a qualitative study performed in the UK about a shift in attitudes on public engagement in health research here.

2.1.2. The importance of engagement

In addition to your readiness level, you should also consider how important engagement is for your research (project) and how you can bring it into practice. Participants can be engaged in research for a wide range of activities, along the whole research cycle. The table below illustrates a few potential tasks that can be performed by participants, grouped per research phase:

FORMULATE A RESEARCH QUESTION	EVELOP OR CHOOSE A METHOD	COLLECT DATA
• Submitting an idea • Expressing concerns • Participating in ideation sessions • Crowdsourcing challenges • ….	• Co-creating citizen science tools • Becoming an interviewer • Developing a measurement device • Defining a survey protocol • ….	• Photographing • Counting • Observing • Using sensors • ….

ANALYSE DATA	REPORT & DISSEMINATE
• Annotating • Transcribing • Interpreting • Calculating • ….	• Proposing new directions for research • Co-authoring a publication • Speaking at a public event • Becoming a project ambassador • …..

Table 5: Examples of potential citizen science activities performed along the research cycle

Apart from activities in the scientific research process, there are also tasks related to the research design and project management. Activities related to the research design and project management refer to developing training materials, establishing a network of participants, organizing communication and support mechanisms, holding meetings and events, etc. Although these tasks are mostly performed by the research team, citizen scientists are also involved in these implementation tasks in some projects. This is often the case in research (projects) with a high level of citizen involvement (cf. section 2.2).

Regardless of the activity participants are performing, it should be ensured that they are engaged in an active, meaningful way . They are involved in the research as co-designers and implementers of research tasks, and not as a research object. Participants are also no longer the target of science communication, but actively engage in the scientific process. As such, research in which citizens participate as respondents in tests or interviews, complete surveys or attend focus groups is not called citizen science. Rather, when citizens are taking an active role in organizing or conducting these tests, interviews, surveys or focus groups, then we do call it citizen science.

Citizen science should not be confused with participation. Many participatory projects actively involve citizens in policy, innovation and other topics. The co-creative methods used in these projects can also be applied in citizen science. However, if these methods do not provide data from which scientific conclusions can be drawn, it is not citizen science. For instance, if these methods are more focused on informing about a particular issue, then we speak of science communication.

If we take these two elements into account, i.e. active, meaningful engagement and participation for purposeful scientific research, it may well be that citizen science does not fit your problem statement. In that case, more conventional methods might be better suited.

SUMMARY

The active participation and engagement of citizens are important components of citizen science. However, engaging citizens just for the sake of reaching participation is not citizen science. Citizens should be actively engaged in the research and the engagement practices should clearly serve a scientific goal.

Reading tips:

- If you would like to learn more about engagement strategies and tools, you can consult this practical guide to communication and engagement in citizen science.
- From a theoretical perspective, science communication models and theories lie on a spectrum from more scientific-oriented to public-centred. You can read more about the deficit model, the dialogue model and the participatory model (of which citizen science is an example) in this publication.
- This publication outlines different models and impacts of public participation in scientific research and discusses it from the perspective of different fields and traditions.

Time to reflect – share your thoughts and opinions:

- What is the importance of citizen engagement in your research (project)? Which type of activities can citizens perform?
- Do you think that one-way communication might be sufficient for your research, without the need to try to make it a citizen science project?
- Do you think you can get more out of your research if you encourage people to contribute to certain research activities?
- Do you think your research would be possible without the contribution of citizens? If yes, what is the added value of the citizen science approach?

34 Pocock, M.J., Chapman, D.S., Sheppard, L.J., & Roy, H.E. (2014). Choosing and using citizen science: a guide to when and how to use citizen science to monitor biodiversity and the environment.

2.1.3. Transdisciplinary research

Citizen science is highly suited to creating connections beyond the discipline-specific approach. You can constitute a research team by combining different scientific disciplines, with researchers from different faculties. Interdisciplinary environments challenge researchers to work together to reach a common goal, to find a common vocabulary and share knowledge. At the European level, Research & Development programmes are calling for higher interdisciplinarity, as a way to come up with quicker and more effective solutions to wicked problems[35].

Furthermore, citizen science is also highly suitable for collaboration with stakeholders from outside academia. In citizen science projects, we often see collaboration among the following actors[36]:

- Civil society: citizens, action groups, civic associations, and other (voluntary) societies where participants can be recruited through a membership base
- Knowledge institutions: research and science institutions, schools, (vocational) universities and educational associations (science museums, libraries)
- Governments: towns and cities, authorities on the local level and other public organisations
- Industry: private companies with expertise in types of sensors, building platforms, legal or judicial advice, communication and media for instance
- Funders: Local, national or European institutions that provide funding or launch grant calls for citizen science

By stimulating transdisciplinary dialogue, citizen science can help in facilitating a shared understanding among stakeholders and the research team. It can also help in making the research more locally relevant, and in providing a holistic perspective of the issues at hand.

SUMMARY

Citizen science is well suited to inter- and transdisciplinary collaboration, particularly if you like to study a phenomenon from different angles. You can collaborate with stakeholders outside of academia, which can make your research more locally relevant, and supported by stakeholders.

Reading tips:

- Read about transdisciplinary research as an interacting thought style here.
- The social sciences and humanities (SSH) are gaining more acknowledgement within interdisciplinary citizen science projects. The liaison emerges through the need to learn more about the social dimensions of the research, and to provide a framework for engagement. Read more about the inclusion of SSH in this article.
- This article stresses the communicative and dialogical translation work that is required in interdisciplinary teams.

34 https://ec.europa.eu/info/sites/default/files/research_and_innovation/groups/rise/allmendinger-interdisciplinarity.pdf
35 Veeckman, C., Van Herck, B., Carpentier, M., Van Laer, J. & Sterken, M., (2021). Citizen Science Roadmap for Local Government. A hands-on manual for citizen science, by and for cities and towns. SCIVIL, Leuven, Belgium.

2.1.4. The spatial and temporal scale

Citizen science is highly suitable if you need to collect or analyse data across large spatial scales over longer periods of time. It is one of the main decision-making factors in why people decide to perform citizen science: teamwork makes the dream work. By engaging a large group of citizen scientists at the same time, the research can be more effectively accomplished. The time and costs needed for the same job performed by more conventional science methods would be considerably greater[37].

For this reason, we see many citizen science projects in the field of environmental monitoring. Citizen science allows increases and improvements in research data and the gathering of data that otherwise would not have been normally available (e.g. in private gardens, or at remote locations). Since many of these projects are repeated over time, it also allows species and ecosystem dynamics related to environmental changes to be studied. In some cases, the citizen science monitoring programmes are even able to collectively produce finer grained and more expansive datasets than official measurement programmes. In this regard, debates are currently occurring concerning whether citizen science data is of sufficient quality to use for policymaking[38].

Tips:

- Official air quality monitoring stations are rather sparse in Flanders (Belgium). Read how the Curious Noses monitoring programme improved the air quality models in Flanders with air quality data on street level thanks to the participation of 20,000 citizens here.
- These applications are used for environmental monitoring purposes with a large spatial and temporal scale: iNaturalist, eBird and Map of Life.
- On national level, we have the database https://waarnemingen.be/ by Natuurpunt and Natagora for observations in nature. For monitoring the weather, there is the database of WOW-BE (Weather Observations in Belgium).

SUMMARY

Citizen science is highly suitable if your study needs to collect data across a large spatial area for a long period of time. By engaging many volunteers simultaneously, it is cost-effective to obtain the data.

37 Kaartinen, R., Hardwick, B., & Roslin, T. (2013). Using citizen scientists to measure an ecosystem service nationwide. Ecology, 94(11), 2645-2652.

38 König, Ariane et al. 'Can Citizen Science Complement Official Data Sources That Serve as Evidence-base for Policies and Practice to Improve Water Quality?' 1 Jan. 2021: 189 – 204. https://content.iospress.com/articles/statistical-journal-of-the-iaos/sji200737

2.1.5. The amount of data that need to be analysed

Citizen science is also highly suitable when large amounts of data need to be analysed. For instance, when you need to analyse a large historical database with manuscripts, satellite images, or webcam photos. If you can make these data available, citizen scientists can help in speeding up the analysis process.

For processing large volumes of data, we often turn to computers to help us out. However, in some cases human ability is still superior. Humans are still delivering better results for sorting tasks, pattern recognition and analysing audio and images. In this regard, citizen science is meeting artificial intelligence nowadays[39/40]. Citizen scientists are helping to train deep learning algorithms based on the classifications performed. Once fully trained, the software applications will carry out automated classifications. Online platforms that can help you with the analysis process are The Zooniverse Platform, doedat.be and velehanden.nl.

Be aware that for processing large volumes of data, the motivation of participants might decrease when tasks are dull and very repetitive in nature. In this regard, gamification and fun elements can help. For instance, the Zooniverse platform offers a space to save, share and discuss objects users have found. Users can post in the 'Talk picture' sharing function and discuss examples that could be mistaken for artwork[41]. Other potential game elements are badges, listing top contributors of the week, unlocking levels, group missions, etc. These elements work very well for younger age groups and extrinsically-driven participants[42].

CASE STUDY: THE ZOONIVERSE PLATFORM

The Zooniverse is the world's largest and most popular citizen science platform for data analysis. Around 1.6 million users are registered who are contributing to research projects in all scientific disciplines. With the help of the volunteers, researchers can analyse their information more quickly and accurately than would otherwise be possible. Via the Zooniverse builder you can create your own powerful interface for data analysis.

More information: https://www.zooniverse.org/

Lastly, if a large amount of data needs to be analysed, you also need to reflect on the complexity of the protocol. For analysing a large amount of data, you will hope to engage large numbers of citizens who are able to finish the task in a fast and simple way.

SUMMARY

You might consider citizen science when you need to analyse a large amount of data or images, satellite images or photos from webcams for instance. If you can make the data openly available, an online web interface can support the analysis process.

39 Ceccaroni, L., Bibby, J., Roger, E., Flemons, P., Michael, K., Fagan, L. and Oliver, J.L., 2019. Opportunities and Risks for Citizen Science in the Age of Artificial Intelligence. Citizen Science: Theory and Practice, 4(1), p.29. DOI: http://doi.org/10.5334/cstp.241

40 Ponti, M., Seredko, A. Human-machine-learning integration and task allocation in citizen science. Humanit Soc Sci Commun 9, 48 (2022). https://doi.org/10.1057/s41599-022-01049-z

41 Greenhill, A., Holmes, K., Woodcock, J., Lintott, C., Simmons, B.D., Graham, G., Cox, J., Oh, E.Y. and Masters, K. (2016), "Playing with science: Exploring how game activity motivates users participation on an online citizen science platform", Aslib Journal of Information Management, Vol. 68 No. 3, pp. 306-325. https://doi.org/10.1108/AJIM-11-2015-0182

42 Bowser, A., Hansen, D., Preece, J., He, Y., Boston, C., Hammock, J. (2014). Gamifying citizen science: A study of two user groups. Proceedings of the Companion Publication of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW Companion '14, 137–140. https://doi.org/10.1145/2556420.2556502

2.1.6. The complexity of the data protocol

The complexity of the data protocol can be another decision-making factor. The data protocol is the way participants are going to collect data in your project. The main rule of thumb is to keep the data protocol as easy as possible. The easier participants can collect data, the more likely you will collect data of high quality. If the data protocol is too difficult, participants might drop out quickly, you might exclude certain groups, or end up with inaccurate data measurements.

CASE STUDY: THE DATA PROTOCOL OF THE EYE FOR DIABETES PROJECT.

The Eye for Diabetes project engaged citizen scientists for annotating retinal images in order to train an algorithm for early disease detection of diabetic retinopathy. The data protocol worked in the following manner. It was decided that the Zooniverse platform would be used to annotate a dataset of retinal images. Therefore, participants had to surf to the Zooniverse portal, where they had to register in order to keep a record of their contributions. A short tutorial explained to the participants how to complete the tasks. Participants were first introduced to simple tasks and, over time, they progressed to more advanced tasks. Overall, it was decided that each image should be annotated by at least ten different participants in order to identify outliers.

Website: https://www.oogvoordiabetes.be/

A straightforward protocol will also help you to engage a large audience. If a lot of data need to be collected or analysed, it is recommended that participants can follow a standardised approach. The protocol should ensure, to the extent possible, that participants are able to collect or analyse the data independently. This is certainly the case when participants collect data at private or dispersed locations.

More complex protocols are also particularly suited to citizen science projects. However, you need to be aware that only a particular profile, and most often an expert profile, will participate (e.g. naturalists, hobbyists, medical professions, etc.).

How-to guides and/or training sessions can support citizens in learning how to apply the protocol. It often helps when the protocol is explained in small and simple tasks. Furthermore, a test session can be organised with friendly users to evaluate the quality of the protocol. These insights can help you to ameliorate the comprehensibility of the task descriptions, and to check the consistency of the data. Test sessions can also help to build in extra validation options in order to ensure that the data is correctly collected or analysed.

Tips:

- Be aware that certain groups might be excluded based on the design choices of your data protocol. Not everyone has access to the Internet or a smartphone or has the appropriate digital skills for your project. If you would like to make your project accessible to everyone, be sure to provide an alternative with the right support.

- Get to know your participating citizens and match their skills and knowledge with your data protocol. For instance, to what extent are citizens familiar with using sensors? Do they have previous experience with annotating images? Small tasks can be outlined for beginners, while more experienced citizens can follow more advanced protocols. Over time, beginners can level up to more advanced tasks.

The template below can help you make design choices for your data protocol[43]:

- **Location** - Are the participating citizens completing the tasks online (e.g. via Zooniverse), on site (e.g. in the garden), or combined? Does the task need to be completed at one particular site or on a large spatial scale? Do participants have access to these sites?

- **Frequency & timing** – Are participating citizens completing the tasks for a one-time event, or on a regular basis? What is the desired frequency? Does the task need to be repeated on a seasonal basis?

- **Citizen science tools** - Which tool is the citizen using to complete the task? Is it a digital tool or another form (e.g. sensors, smartphone applications, websites, measurement kits, paper forms, etc.)? Is the tool easy to use? Is the tool freely available?

- **Efforts** – How much time does it take for a citizen to complete a task? Is the task too demanding for the citizen? Does the frequency encourage participation?

- **Citizens' skills and knowledge** – Does the task match the skills and knowledge of the citizens? Is there a possibility to advance the type of tasks over time?

- **Training and support:** Is it necessary to publish a how-to guide? Is it necessary to organise a training session (on-site, or online)?

- **Data quality** – Which validation mechanisms can be provided in order to ensure data quality (e.g. request response, validation by expert users, number of entries, fixed drop-down menus, etc.)? You can find more information about this aspect in Module III.

SUMMARY

The main rule of thumb is to keep the data protocol as easy as possible. A more complex data protocol is also suitable for citizen science but will only work for a particular profile of participants. A successful protocol design for citizens is one that keeps them well practised and motivated to gather consistent data.

Reading tips:

- his guidebook includes a decision framework for citizen science in the field of biomonitoring, and includes several questions on the data protocol.

- The data charter for citizen science (available in Dutch and English) can help you with further questions on data quality. This data charter is published by Scivil, the Flemish Knowledge Centre on Citizen Science, in collaboration with Digitaal Vlaanderen.

The online MOOC of the WeObserve project teaches you to capture and analyse data and use the findings to take action. The MOOC is particularly relevant for citizen science projects and citizen observatories focusing on environmental monitoring.

43 Based on info published in: 1) Mondardini, Maria Rosa; Roffler, Ursina; Eliseeva, Tatiana; Höhener, Olivia; Kretzer, David Michael; Lenart-Gasiniec, Regina; Maatz, Anke; Martin, Mike; Tönsmann, Susanne; Tsianou, Evgenia; Wiederkehr, Stefan (2021). Practicing Citizen Science in Zurich: Handbook. Zürich: Citizen Science Center Zurich, and 2) Pocock, M. J., Chapman, D. S., Sheppard, L. J., & Roy, H. E. (2014). Choosing and Using Citizen Science: a guide to when and how to use citizen science to monitor biodiversity and the environment. NERC/Centre for Ecology & Hydrology.

2.1.7. Promotion of scientific learning

Through the programme, pupils and students can take part in science through fun and hands-on activities. In these projects, researchers and school/student communities are working in tandem. On the one hand, observations can be collected that advance real science and, on the other hand, curiosity and learning are sparked.

Engaging youngsters, students and teachers in a citizen science project can help promote scientific literacy. Pupils and students can connect with scientific knowledge and be inspired about the work of scientists. They learn how to ask scientific questions, run experiments and can draw evidence-based solutions. Researchers can also train teachers in scientific inquiry and research methodologies. This ensures that the activities are meaningful for all, and that teachers can support the activities to guarantee good quality data.

Different citizen science approaches for promoting scientific learning can be applied. Firstly, you can choose to design your project specifically for school education, whereby the pupils or students are invited to participate as part of their school curriculum. In specific cases, citizen science also has the potential to activate Science, Technology, Engineering and Mathematics (STEM) learning[44]. A second approach is that you extend the scope of your project with (in)formal education and classroom practices, by developing specific information packages for instance. Formal learning generally occurs in the classroom with clear learning objectives, whereas informal learning takes place outside the classroom, or after school, in places like museums nature clubs, fablabs, etc.

If you like to work to implement citizen science in formal education, then the following tips can help you:

- Decide in advance which age group is suited to your project
- Define the learning objectives and attainment levels and mention these specifically in your communication to the teachers. With this information, they can determine whether your project fits their lessons
- Adapt your activities to the school context (take into account holidays, school hours, ...)
- If possible, collaborate and co-design the materials together with a teacher, or consult a teacher from time to time about your approach so that it can be well aligned with the classroom context

Tips:

- If you would like to read more about citizen science in the classroom, you can check the materials developed by the BRITEC project. They offer different guidebooks and also a MOOC on citizen science education.
- This article talks about the challenges and opportunities of citizen science projects in formal and informal learning environments.
- There is a European Citizen Science Association (ECSA) working group on learning and education in citizen science, which helps to develop the informal learning and educational aspects in citizen science projects. Learn more about this working group here, or read their book chapter with main highlights here.

SUMMARY

If you would like to promote science learning among school communities, then you can consider a citizen science approach. Citizen science is a great opportunity for pupils, students and teachers to immerse themselves in science activities.

44 https://citizenscience.org/wp-content/uploads/2017/05/AfterSchoolSTEM-170510.pdf

2.1.8. The available project budget

Citizen science can be a cost-effective way to gather a vast amount of data in a short period of time. With the help of citizen scientists, scientific information can be collected on scales and at resolutions that would have not been possible for individual researchers or whole research teams. It is however a misunderstanding that a citizen science project is free of charge. There are several costs, different to regular research projects, that you need to consider.

Firstly, there are **personnel costs** related to the recruitment and engagement of citizen scientists. Participants should be looked for, engaged and motivated to remain in the project. Time should also be allocated to the training of participants. Trainings can be organized in person or online, with supervision also during the data collection. Trainings and the establishment of a protocol are vital for ensuring data quality. Personnel costs will also be dedicated to communication and awareness raising activities. Communication is a vital aspect in a citizen science project. Ideally, your project has a science communicator who makes sure that messages, research results included, are communicated in an accessible and understandable manner.

Furthermore, there are **material costs**, but this does not always have to be the case. Material costs can be very diverse, ranging from measurement kits to a project website. These costs can be limited if the project can rely on open-source materials.

These types of costs can be a potential burden if you want to start with a project. There is a potential risk of not being able to recruit enough participants, in keeping them motivated, or in having sufficient materials. Furthermore, if the budget is limited or only short term, you also run the risk that your research project will be discontinued quickly after its ending.

Tips for finding financial resources:

- Look for sponsors or raise funds from a wide audience through crowdfunding.
- Integrate a citizen science approach in proposals of regular funding streams. The granting of subsidies for this type of research is not limited to specific citizen science calls.
- Local government often do not have subsidy lines for citizen science projects. Instead, localized citizen science initiatives can often rely on support if there is a link with existing grant lines in connected social domains (e.g. mobility, circular economy, health, etc.).
- Participants can cover a portion of the costs. If you are transparent about the costs and if the intrinsic motivation to participate is high, participants are often willing to contribute financially.
- Build a partnership around your project. That way, not only the efforts but also the costs can be shared.
- Save costs by using open-source software and freely available applications. Developing equipment by yourself is very time-consuming and costly.

SUMMARY

It is a misunderstanding that citizen science is a cheap (or even cost-free) approach to collecting data. Although data can be collected in a cost-effective manner, there are several costs that you need to consider which are different from conventional science. Investment needs to occur for costs related to recruitment, engagement, communication and training of participants. If your project is low on budget or builds on short-term `flashpoint funding', then it is advised that you look for (additional) financial resources to make your project plan more solid and durable.

Reading tips:

- This thesis researches the cost savings of citizen science projects by comparing three projects with their professional equivalent.
- This article examines the value of citizen-generated data, with a methodology to compare the value with existing environmental observations and the evolution of their costs in time.
- This article presents the costs incurred for monitoring marine invasive species. It is presented as a low-cost monitoring campaign, for which the strategy can be easily replicated.

Time to reflect – share your thoughts and opinions:

- This article outlines seven successful strategies when applying for citizen science funding. What is your experience in applying for citizen science funding?
- Read this opinion piece by Dr. Paul Drachman on economic considerations of citizen science projects. The attention paid to economic factors in citizen science is not particularly high, or not the decisive factor, in comparison with other values such as education and the scientific significance of the project. What is your opinion on this?
- How do we guarantee that research involving citizen scientists does not discontinue quickly after the project ending?

2.2. TYPOLOGIES OF CITIZEN SCIENCE PROJECTS

Once you have decided that citizen science is the right approach for your research, the next step is to reflect upon the type of citizen science project. In scientific literature, there are several typologies which classify citizen science projects. We discuss typologies based on the degree of participation and the primary project goal.

2.2.1. The degree of participation

The most commonly used typology by citizen science practitioners is based on the different degrees to which participants are engaged in the scientific process. These models stem from the broader field of Public Participation in Scientific Research (PPSR), which covers different forms of citizen involvement in research. The degree of participation is defined as the extent to which citizens are involved in the process of scientific research[45].

Based on the degree of participation, Shirk et al. categorize projects into five models[46]:

TYPE	BENEFITS FOR SCIENCE	EXAMPLE
Contractual	Citizens ask professional scientists to conduct a specific scientific investigation. Citizens can exert a control over the research agenda and the resulting knowledge produced. However, further participation in the remainder of the research process is limited.	The 'Science Shop' is a project of the VUB, the University of Antwerp and the KU Leuven. It is an example of a contractual project, whereby not-for-profit organisations and civic organisations can raise a question, a concern or an idea for a research project. The Science Shop matches the input with students and promotors.
Contributory*	The project is designed by scientists and citizens are generally invited to gather data (over wide geographic areas and/or over long spans of time). The researchers decide upon the research focus and the protocol for data collection.	In the citizen science project Vespa-Watch, members of the public are asked to look out for Asian hornets (and their nests). This exotic wasp species is a threat to the native bee. When they spot the insect, citizens upload a photo and the GPS coordinates to the project website. Research scientists working at Ghent University use the data to map out the dispersal of the species. The citizen scientists merely supply the data.
Collaborative*	The project is designed by scientists, and citizens can take part in different phases of the research process. Apart from data collection, they can also participate in the project design, the analysis, and dissemination of findings.	In 2014 the project AIRbezen in Antwerp involved a large group of citizens who collected data (they submitted the leaves of a strawberry plant, which they had left out on the window ledge, for an analysis of the air quality). Research scientists at the University of Antwerp were to collaborate in the first phase of the project with volunteers from the Stadslab 2050 group. They and the volunteers brainstormed how the study would be done and what it should be called. This small group of volunteers also helped with the plant distribution and communication.
Co-created*	The project is designed by scientists and citizens. The question or issue is defined by the public. All of the research steps leading on from this are taken by the citizens in consultation with the researchers.	In Antwerp, a citizens' observatory was set up under the European Ground Truth 2.0 project. Scientists, policymakers and citizens regularly meet around the table to consider study areas and solutions for environment-related challenges like air pollution, drought, flooding, lack of greenery, and heat. In 2019 they began work on the subject of heat stress.

45 Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., ... & Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. Ecology and society, 17(2).

46 Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., ... & Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. Ecology and society, 17(2).

Collegial contributions	This project is designed by amateur scientists, or hobbyists, such as amateur astronomers, archaeologists and taxonomists, who often work on their own. They conduct research independently.	Amateur scientists or hobbyists are often working independently, or are connected with fablabs, or hobby clubs for instance.

*Table 6: Five project models based on the degree of participation by Shirk et al. (2012). Projects indicated with an * are also defined by Bonney et al. (2009)*[47]

The table above lists the projects from a low to a higher level of engagement with the research activities, with the contractual and collegial models at the far boundaries of the PPSR spectrum. The three middle models in the table, which clearly demonstrate a range of public participation activities in scientific research, align closely with models defined by other scholars. Although authors are using different labels for their models, the projects are all categorized according to the degree of participation – regardless of the field of practice. For instance, Haklay also defined a common-known typology based on the level of participation and engagement in citizen science projects[48]:

TYPE	DESCRIPTION	EXAMPLE
Crowdsourcing	Citizens only offer resources in terms of time and devices (e.g. volunteered computing and citizens as sensor carriers). The cognitive engagement is minimal.	The World Community Grid projects make use of the com- puters of thousands of volunteers. You create an account on the website and download a tool to your computer. The application monitors your computer for spare computing power and that power is used to conduct virtual experiments. Research has been done in areas such as childhood cancer. The citizen scientists play a passive role but are notified about the research being done.
Distributed intelligence	Citizens collect data or carry out a simple interpretation activity or help to categorise the research material.	Citizen scientists in the Oog voor Diabetes (Eye For Dia- betes) project examine the retinal images of diabetes pa- tients online. They note any signs of diabetic retinopathy, a disorder which can lead to blindness. The catalogue of images can then be used to teach an algorithm to recog- nise the disorder, paving the way for screening by artificial intelligence.
Participatory science	Citizens are engaged at the start of the project. They help define the problem, collect data, and then help the scientists analyse the material. The researcher still has a high level of control over the analysis and interpretation.	The idea for CurieuzeNeuzen 2016, in which members of the public measure the air quality in Antwerp, arose in the Ringland community group. Scientists and the Flemish Environment Agency (VMM) then became involved in the research.
Extreme citizen science	Researchers and citizens define the various steps in the research process together. However, the role of the scientist is confined to that of facilitator. This opens up the possibility of citizen science without professional scientists, in which the whole process is carried out by the citizens.	Using the so-called flitsfiets (flashbike), a DIY bike, the ac- tion group 30Max records speeding offences in the centre of Antwerp. The group aims to use the data to show that the speed limit is rarely observed and hopes to force the introduction of measures. The action group itself came up with the idea for the flashbike. Researchers from the imec City of Things helped find the technology and data to make it work.

Table 7: Four project models based on participation and engagement in citizen science projects defined by Haklay (2013).

47 Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. Online submission.

48 Haklay, M., 2013, Citizen Science and Volunteered Geographic Information – overview and typology of participation in Sui, D.Z., Elwood, S. and M.F. Goodchild (eds.), 2013. Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice. Berlin: Springer. pp 105-122 DOI: 10.1007/978-94-007-4587-2_7

It is important to mention that these typologies are not normative rankings[49]. Not every project needs to engage citizens in every stage of the scientific process. The level of engagement has a lot to do with the research objectives you have in mind. Aspiring to a higher level of engagement is thus not necessary, although it will lead to different types of outcomes for the public. Likewise, engaging citizens more deeply in the research process does not mean that the collected data will be less scientifically interesting.

Tips:

- Think carefully about your research design and choose the type of model with the end goal you have in mind. Will a given degree of citizen participation be sufficient to achieve a desired outcome?

- You do not have to apply one degree of participation in your research (project); you can also facilitate multiple levels. Citizens will inherently create their own individualized experience, regardless of the predominant model of participation in your research. As such, you might have a core group of participating citizens who are engaged in all stages of the research process, while the majority only contribute with data collection or creation.

- You can modify your project design along the project lifetime. This is particularly useful when you notice that your participating citizens are changing their interests and motivations to participate in the research (project). This will support sustained, or continued, citizen participation in the project.

2.2.2. The project goal

A different way of categorizing citizen science projects is by focusing on the primary target goal of the project. Wiggens and Crowston clustered projects based on the explicit goals mentioned in the project materials, and found five different types of citizen science projects[50]:

TYPE	DESCRIPTION	EXAMPLE
Action	This project is organised by the public (e.g. grassroots organisations), and not conceived by scientists. They focus on local concerns and use scientific research as a tool to support the civic agenda. Professional scientists are engaged as consultants. The projects are often small-scale and strongly localized.	In 2015, the project 'ADEM' measured the air quality in Ghent through the usage of low-cost sensors placed on a bike. The project was organised by a group of interested citizens and the organisation Timelab.
Conservation	These projects are mostly initiated by researchers or by governmental actors. They are primarily focused on data collection for resource management decision-making, and with promoting stewardship and awareness. They are often long-term and large-scale.	Through the project 'Smart Waterland', the City of Roeselare is trying to collect precipitation data via a fine-grained network of pluviometers with the help of citizens. The data are assembled via a platform (Internet of Things) in order to be able to approach water management in the city in a smarter way. The information collected via various pluviometers can be used immediately to steer the water system or to intervene and start emergency services for approximately 2 hours. This system can help Roeselare to respond to climate change.

49 Hecker, S., Bonney, R., Haklay, M., Hölker, F., Hofer, H., Goebel, C., Gold, M., et al. (2018). "Innovation in Citizen Science - Perspectives on Science-Policy Advances.". Citizen Science: Theory and Practice, vol. 3, nr. 1, pp. 1–14.

50 Wiggins, A., & Crowston, K. (2011, January). From conservation to crowdsourcing: A typology of citizen science. In 2011 44th Hawaii international conference on system sciences (pp. 1-10). IEEE

Investigation	These projects are mostly initiated by academics or by non-profit organisations. They focus on scientific research goals with educational materials for the public. They often operate on a larger physical scale.	The citizen science project 'Stiemerlab' starts from the premise that citizens of Genk, local residents and local organizations can actively contribute to assess and address the water quality issues of the Stiemervallei. The project actively involved citizens, for example by training them as citizen scientists to collect data on the water quality in the Stiemerbeek using sensors. The project ran from 2020 till 2022, and was initiated by LUCA School of Arts in cooperation with VITO, UHasselt (Centre for Environmental Sciences), the City of Genk and Vlaamse Milieumaatschappij (VMM).
Virtual	These projects are initiated by academics. Their primary goal is similar to investigation projects, but all the project activities are ICT-mediated. The projects make use of custom web platforms or open-source technologies.	The Galaxy Zoo project is a crowdsourced astronomy project which invited citizens to assist in the classification of a large number of Galaxies. Galaxy Zoo is part of the online platform Zooniverse. There have been 15 different campaigns since 2017.
Education	These projects are organised top-down and mostly involve multiple types of partner organisations. Their primary goal is focusing on education and outreach. The projects can be further subdivided into formal and informal learning.	The Airbezen project in 2015 focused on the involvement of schools in East-Flanders (Belgium) to measure the air quality with the help of strawberry plants. An educational package was provided for primary schools, and science events were organised for secondary schools. Secondary schools were given the opportunity to analyse the samples themselves in the lab.

Clustering projects based on their goals is to run the risk of thinking simplistically. Many citizen science projects have multiple objectives, often balancing between scientific and educational goals. Projects can originate at the university or at research centres, in the public realm, or both. The taxonomies provided can be useful as a starting point to help you reflect on the type of citizen science research. However, in reality, these taxonomies might blur, with different crossovers in features. Therefore, we recommend reflecting on these typologies as a starting point, from which you then implement the right customized design for your research (project).

Reading tips:

- Based on the former mentioned typologies of Bonney et al., Shirk et al., and Wiggens and Crowston, this article integrates all typologies into one quadrant based on the locus of knowledge creation and the focus of the project activities.

- The typology of van Noordwijk et al. is focused on distinct participating citizen groups and their motivations to participate. The article describes four different types of projects: place-based community projects, captive learning projects, interest group projects and mass participation projects.

- To further grasp the variety of citizen science inquiries, Fan & Chen look at it from a political angle and define models related to how citizenship is built into the research (project). Four models are described in their article, namely 'Cosmopolitan Community knowledge', 'Science, State and Citizen', 'Democracy and Justice' and the fourth type 'Civic commons and techno-social infrastructures'.

Time to reflect – share your thoughts and opinions:

- Which model does your research (project) resemble? What is or are the different degrees of citizen participation?
- If it were feasible, would you set up your research exclusively online?
- Extreme citizen science projects challenge the scientific culture in the sense that it requires scientists to engage deeply with social and ethical aspects of their work. This potential change process is framed by Haklay with the following phrase: *'the emphasis is not on the citizen as a scientist, but on the scientist as a citizen'*[51]. What is your opinion on this?

51 Haklay, M., 2013, Citizen Science and Volunteered Geographic Information – overview and typology of participation in Sui, D.Z., Elwood, S. and M.F. Goodchild (eds.), 2013. Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice. Berlin: Springer. pp 105-122 DOI: 10.1007/978-94-007-4587-2_7

MODULE 3: CRUCIAL DESIGN FACTORS FOR A CITIZEN SCIENCE PROJECT

Module 3 describes some crucial design factors for realizing successful citizen science research. These design factors relate to specific processes and mechanisms that can either drive or hinder the success of citizen science. The definition of what 'successful' citizen science is will vary from context to context. Success might be defined by the amount of gathered data and the number of research publications, or by the established social impact. Success is thus context-specific and will be in line with the objectives and goals of the research (project).

The following design factors are described in this module: (1) A communication and feedback culture, (2) Motivation strategies to participate, (3) Mechanisms for ensuring data quality, and (4) Usage of citizen science platforms for data management. This list of design factors is not exhaustive and will be further updated based on good practices at the EUTOPIA TRAIN universities, and more broadly.

At the end of this module, you should be able to understand crucial design factors and have some general guidance at hand for starting your citizen science research (project).

3.1. A COMMUNICATION AND FEEDBACK CULTURE

A crucial design factor in citizen science is the set-up and maintenance of a communication and feedback culture[52]. Communication is a vital aspect of citizen science, and it is a necessary part in every step of the research process. Communication activities will be needed for recruiting and engaging citizen scientists, increasing the visibility of your research (project), informing about the project's results and outcomes, etc. It takes good practice to communicate effectively, and you may not underestimate the amount of time that you will spend communicating with your target audiences. Ideally, your research (project) will have a community manager, a science communicator and a science trainer who can look after these activities:

- The **community manager** is the main point of contact for your citizen scientists if they have any questions. In some research projects, it will be necessary to have a forum or a central support service. The community manager is proactive in sharing information and news, and in finding the right answer to questions from citizens. It is not necessary to be available 24hrs, but to provide an answer within a respectable amount of time (within 1 to 3 days). Furthermore, the community manager can also motivate participating citizens to help each other out[53]. As such, participating citizens can also become ambassadors for your research (project).

- The **science communicator** ensures that content is easily understandable and accessible to a broad audience. The science communicator proofreads the texts and checks if it adheres to inclusive communication principles.

- The **science trainer** makes sure that citizen scientists are properly trained for collecting or analysing data by providing manuals or support on the ground.

52 Capdevila, A. S. L., Kokimova, A., Ray, S. S., Avellán, T., Kim, J., & Kirschke, S. (2020). Success factors for citizen science projects in water quality monitoring. Science of the Total Environment, 728, 137843.

53 Source: https://www.futurelearn.com/courses/weobserve-the-earth

Now, what is good communication? There are many factors in place that affect the success of communication activities[54]. Overall, it is recommended that a communication plan for your research (project) is worked out. A communication plan is a detailed description of all communication steps by which you plan to engage your target audiences. You list the steps in chronological order, and you link them with the relevant target audiences, the tools and channels, and the aims you hope to achieve. You write your communication plan in the planning phase of your research (project) and adjust it when the project is live. An important point is to set a budget. This will help you to set priorities; do you plan to evenly spread your resources over the lifetime of the project, or do you plan some peaks in your communication? The communication plan also allows you to evaluate how successful the activities have been at particular moments in the research (project).

A couple of factors are listed below that need to be considered for a successful communication strategy[55]:

- **Identify your target audiences:** When identifying your target audiences, you can categorize them into primary, secondary and intermediary target audiences. The primary target audience will be the group of citizens who feel highly engaged with your research (project), and who are the most affected by the research aim. This group will contribute the most when it comes to collecting or analysing data. A secondary target audience is a group who is aware of, but not directly involved in, the project. A secondary target audience might become a primary target audience, a government authority which is interested in your research for instance. Lastly, an intermediary target audience is a network, an organisation or a person that might connect you to others, a teacher forum if you like to engage youngsters for instance.

- **Get to know your target audiences:** The better you understand your target audiences, the more effective and personal you can make your communication. In listing your target audiences, it is also good to have specific details about them. What is the size of the group? What is the average age? What is the gender distribution? And what is their level of education regarding the research topic? What are their motivations to join your research (project)? Not understanding your target audiences, and not knowing what stimulates them to be part of citizen science, is one of the biggest pitfalls. In the planning and design phase of your research, you can look into already established research studies to see if you can find any interesting information related to your target audience. You can also decide to develop a short intake survey once citizens subscribe to your research. In this way, you can log their former experiences, knowledge and motivations, and employ the right strategies and tools to recruit them.

- **Use a diverse mix of communication channels and tools:** You can use a wide variety of channels and tools for supporting your communication activities, either digitally, on paper or face-to-face. When identifying and describing your target audience, you can also match it with the most efficient communication channels and tools. Choosing the right medium ensures that your message arrives to your intended audience, and increases the chances that your audience reads, hears, or sees your messages. Depending on the purpose of your message, you might choose a different medium of communication. For instance, if you want to inform and train citizens, you might choose physical workshops so you can provide the opportunity for asking questions. On the other hand, if you would like to inform about an urgent issue related to data collection, you might choose social media or personal e-mails. Try to be creative in the mix of media that you choose for your communication activities. Presentations with lengthy explanations should be balanced with playful, social events. Furthermore, using a varied mix of media will also affect the diversity of your project participants. Launching an open call via social or mass media will allow you to reach a huge number of potential scientists. If you combine this approach with more targeted communication, such as collaborating with intermediary organizations, then you will be able to reach out to more specific profiles.

- **Use of language[56]:** The language, specifically the tone of voice and its terminology, matter greatly when communicating with your target audiences. Getting the 'wrong' language might exclude citizens from the communication processes. Therefore, it is crucial that you reflect on how inclusive the language used is. For instance, is the language adapted to audiences of different cultural and literal backgrounds? Are gender differences taken into account? And are you using understandable language? Which terminology are you using for describing participating citizens (cf. Module I)? Talking with participating citizens can help you to understand how they feel affected by it, and might enable you to co-create a more inclusive and understandable language.

54 Rüfenacht, S., Woods, T., Agnello, G., Gold, M., Hummer, P., Land-Zandstra, A., & Sieber, A. (2021). Communication and dissemination in citizen science. In: K. Vohland et al. (eds.), The Science of Citizen Science, 475. https://doi.org/10.1007/978-3-030-58278-4_24

55 The list is distilled from: Veeckman, C., Talboom, S., Gijsel, L., Devoghel, H., Duerinckx, A. (2019). Communication in Citizen Science. A practical guide to communication and engagement in citizen science. SCIVIL, Leuven, Belgium ; Rüfenacht, S., Woods, T., Agnello, G., Gold, M., Hummer, P., Land-Zandstra, A., & Sieber, A. (2021). Communication and dissemination in citizen science. In: K. Vohland et al. (eds.), The Science of Citizen Science, 475. (https://doi.org/10.1007/978-3-030-58278-4_24) and the online MOOC of https://www.futurelearn.com/courses/weobserve-the-earth

- **Open communication[57]:** Citizen science is a two-way communication process between researchers, participating citizens and other stakeholders (e.g. policymakers, interest groups, etc.) involved in the research (project). When planning your project, you have to reflect on how you can stay in touch with participating citizens, but also how they can connect with you and other members of the community. You can question the preference of communication channels and evaluate what type of information they like to receive. During the executing phase, it is of critical importance that (personal) feedback is provided as it gives recognition for the citizens' contributions. If feedback cannot be provided immediately, then you can send a message that the collected data was successfully received and that the data will be validated within a certain period of time. Drop-out can occur at this stage due to a lack of openness about the results. After completing the task, participating citizens are eager to know more about the results. Therefore, it is recommended that once a task is completed you are open about the further steps in the research (project), and you already provide some first insights through simple visualizations or statistics (e.g. the number of contributions, explanations about the analysis methods, insights into citizens' profiles, etc.). During the final stage of the research (project), the final results are shared with the target audiences. Again, it is recommended that a two-way dialogue is stimulated and that the research results are not just presented during an event or published online through a downloadable report. Interactive workshops can ensure the sustainability of the results and can provide space for mutual learning related to (policy) recommendations or future research trajectories.

A PRACTICAL GUIDE TO COMMUNICATION AND ENGAGEMENT IN CITIZEN SCIENCE:

It takes practice to stay open, accessible and inviting through communication. This practical guidebook equips you with a few tricks of the trade.

The **first part** of the book focuses on the building blocks of a good communication plan. A communication plan reflects upon the project objective(s), the level of engagement, the target audience and its motivations and, finally, the evaluation of success.

The **second part** of the book focuses on tactics and tools that you can use for the engagement strategy. An engagement strategy helps you to reflect upon the expectations, motivations and behavioural aspects of your target audience to keep them on board in the long term. Six tactics and tools are provided, such as storytelling, gamification, and usage of social media, to support either initial or continued participation.

The **third and fourth** part of the book provide practical tips and tricks, as well as a template to start drafting your own communication and engagement plan.

The guide was published in 2019 by Scivil, the Knowledge Center on Citizen Science in Flanders, and in collaboration with SMIT, EOS Wetenschap and Tales and Talks. The content of the guide is based on studies of citizen participation and the real-life experience of science communicators. This guide is for anyone who finds themselves communicating and engaging with citizen scientists.

You can download the guide here in English and in Dutch.

SUMMARY

Communication is a vital aspect of citizen science. A two-way dialogue is set up between researchers and target audiences, whereby values such as interaction, providing feedback, sharing knowledge and mutual learning are put up front. Good communication takes practice. Make sure there is a dedicated budget and team for managing these activities.

56 Rüfenacht, S., Woods, T., Agnello, G., Gold, M., Hummer, P., Land-Zandstra, A., & Sieber, A. (2021). Communication and dissemination in citizen science. In: K. Vohland et al. (eds.), The Science of Citizen Science, 475. https://doi.org/10.1007/978-3-030-58278-4_24

57 Source: https://www.futurelearn.com/courses/weobserve-the-earth

Reading tips:

- The Scottish National Standards for Community Engagement might provide a useful reference point for ensuring high-quality and effective engagement processes. There are ten standards in total for setting up successful engagement with stakeholders, focusing on support, planning, methods, working together, improvement, etc. Indicators are provided for each standard, which can be incorporated into your communication and engagement plan.

- If you are interested in learning more about inclusive language, you can check out the book 'Inclusive communication' by Hannan Challouki. Furthermore, the organisation 'Wablieft', centre for clear language, helps you with writing accessible texts (for vulnerable groups). They organize workshops and also offer paid proofreading and editing services.

- This article by by de Vries et al. (2019) performed a literature review on citizen scientists' preferences for communication of scientific outputs.

Share your thoughts and opinions - Time for reflection:

- Would you consider using mass media to promote your research (project)? Do you have any doubts or concerns?

- Do you have the necessary capacities in your team to support communication activities? How are roles divided?

- What are your experiences and tips for using social media for communicating about your research (project)?

3.2. MOTIVATIONAL STRATEGIES FOR PARTICIPATION

In addition to a communication plan, it is also effective to have an engagement plan in place[58]. Engagement stands for the active involvement of citizens in your research activities and will be defined by the chosen level of participation (cf. Module II). Therefore, an engagement strategy will focus on the identification and monitoring of motivations which support or prevent citizen scientists from taking part in your research (project). In line with citizens' expectations, the engagement strategy will also propose (new) tactics and tools to secure continued participation in the long term. During the implementation phase, the communication and engagement plan will be closely interconnected with each other. For instance, if monitoring tools reveal that participation rates are dropping, then new communication activities can be planned that stress particular motivations to take part in the project.

Motivations to take part in citizen science research can be very diverse, but they are mostly intrinsically driven[59]. When citizens are intrinsically motivated, they engage in the research (project) because it is personally rewarding, or they find enjoyment in the process itself. If they were participating out of a reward or social status gain, then citizens would be more driven by external drivers which are not always directly related to the project. In most cases, citizens are motivated to take part because they like to contribute to science, or because they have an interest in the particular research topic. In citizen health science, the motivation is strongly linked to a personal interest in contributing towards a treatment or cure[60].

58 Veeckman, C., Talboom, S., Gijsel, L., Devoghel, H., Duerinckx, A. (2019). Communication in Citizen Science. A practical guide to communication and engagement in citizen science. SCIVIL, Leuven, Belgium.

59 Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. Contemporary Educational Psychology, 25(1), 54–67. https://mmrg.pbworks.com/f/Ryan,+Deci+00.pdf

60 Wiggins, A., & Wilbanks, J. (2019). The rise of citizen science in health and biomedical research. The American Journal of Bioethics, 19(8), 3–14. https://doi.org/10.1080/15265161.2019.1619859.

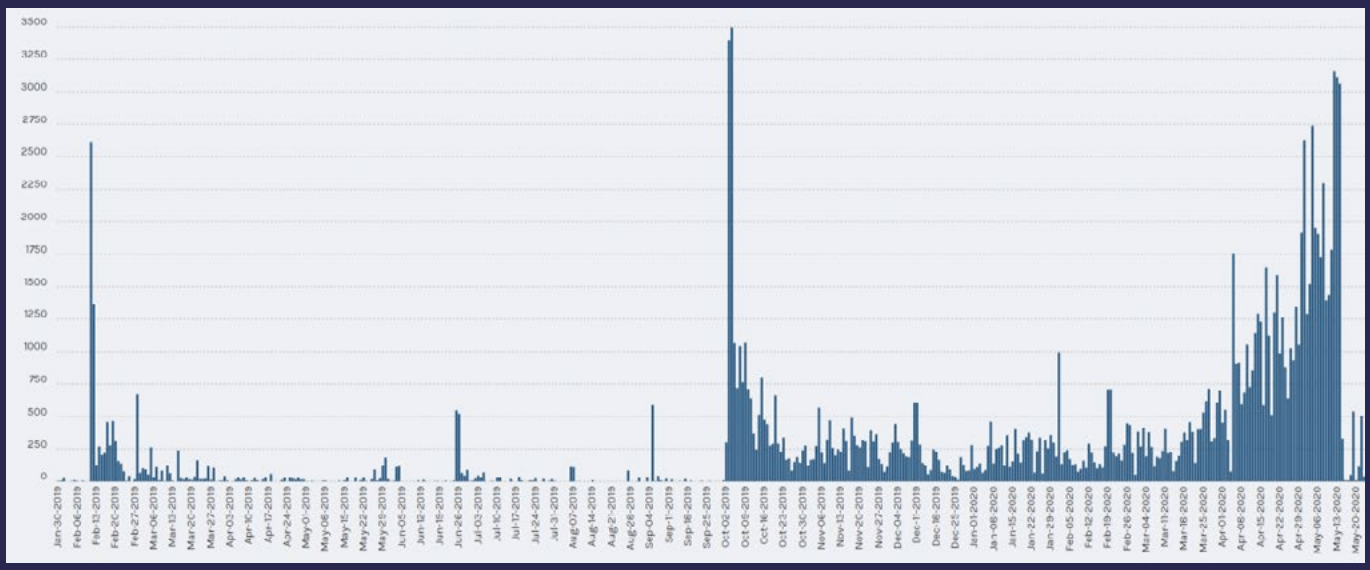
CASE STUDY: REASONS FOR MONITORING AIR QUALITY

As part of the development process for its engagement strategy, the hackAIR project surveyed 370 potential citizen scientists. An online questionnaire gauged motivations for, and barriers to, air quality monitoring and measurement in the neighbourhood. The leading motivations were: general curiosity about the measurement results (56%), concern about the local air quality caused by the perception of living in an area with poor air quality (43%) and personal health problems (30%). These reasons were used as triggers during opportunities to communicate later in the project.

Motivations can also change over time. At the beginning of the project, citizens are mostly driven by the desire to learn, general curiosity and out of interest. Over time, these motivations rather shift towards scientific learning, social connections, and feeling appreciated . Be aware that not everyone will stay till the end of the project. The drop-out rate is usually the highest at the time of initial participation, or just after it. This is mostly due to the usage of jargon, or a non-user-friendly application or data protocol. The drop-out after a longer term of participation will be mostly due to a lack of openness about the scientific process, lack of feedback about the results, and a lack of recognition.

CASE STUDY: ENGAGEMENT METRICS OF THE EYE FOR DIABETES PROJECT

'The Eye for Diabetes' project motivated citizens through Zooniverse for training an algorithm for identifying symptoms of diabetic retinopathy. Citizens were invited to annotate retinal images for symptoms of the disease. During the lifetime of the project (January 2019-June 2020), a total of 3,950 citizens registered to take part in the project. The graph below displays the number of contributions made on the Zooniverse platform over time. Halfway through the project, the number of contributions increased due to making the platform more accessible to international users by adding an English version. Peaks in contributions could also be correlated with organised events, and the start of the COVID-19 pandemic. The statistics suggested that half of the classifications were performed by non-registered users. On average, one citizen scientist watched and labelled 24 retina images, while the top contributor labelled 1,000 images. This shows that only a small percentage of the participating citizens were hardworking and loyal to the project, while the majority of contributions were made by a larger group of citizens who passed by unplanned.



61 Rotman, D., Hammock, J., Preece, J., Hansen, D., Boston, C., Bowser, A., He, Y. (2014). Motivations Affecting Initial and Long-Term Participation in Citizen Science Projects in Three Countries. https:// doi.org/10.9776/14054

SUMMARY

It is recommended that the participation rates and the motivations of citizen scientists are monitored over time. Motivations can be very diverse, and what works for one group of citizens might be less effective for other groups. Based on gathered insights, you will have to adapt your engagement and communication plan, and perhaps also other elements of your project design, if the drop-out is caused by accessibility issues.

Reading tips:

- The motivations of citizen scientists are usually investigated through social science research, by organizing surveys or in-depth interviews. If you would like to collect information about the motivations of the citizen scientists in your research (project), you can use the following questionnaire by Levontin. The questionnaire consists of 18 categories, with 58 items in total. Depending on the scope of your research (project), you can select the most appropriate items.

- For monitoring the participation rates in your research (project), you can rely on several engagement metrics. Aristeidou et al. (2017) propose looking into the activity ratio (the number of days a participating citizen was active and contributed versus the days s/he remained in the project), the activity duration (the number of days a participating citizen is linked to the project versus the total number of days) and the lurking ratio (the number of days a participating citizen was browsing content on the citizen science platform, but not contributing). Based on these metrics, you can categorize your participating citizens into different engagement profiles (e.g. hard-working volunteers, loyal volunteers, lurkers, etc.).

- This toolkit of citizenscience.gov provides further information about how you can build a community. Tips are provided for knowing, engaging and nurturing the community.

- The BiodivERsA project provides an interesting handbook on stakeholder engagement in research projects. It includes practical guidance for better planning and engaging with non-academic stakeholders, including policymakers.

Share your thoughts and opinions - Time for reflection:

- Do you have any tips on how you can manage the expectations of participating citizens in your project? Citizens may expect to see rapid change, while in reality this might not be the outcome of the research (project).

- What are potential drivers and barriers for participating in your research (project)? Are there clearly stated benefits for participating citizens?

- How can you ensure continued participation in your research (project)? Which tactics and tools could help?

3.3. MECHANISMS FOR ENSURING DATA QUALITY

Regarding the quality of the citizen science data, there are certain questions and doubts that can arise. Are citizen scientists able to gather reliable data? Can they intentionally or unintentionally influence the results? And are you measuring what you intended to measure in a correct way?

As a researcher, you are looking for scientific accuracy in the data for achieving your analytical objectives. If policymakers are involved in the research (project), they might have other expectations and needs regarding the data. Policymakers do not want to run the risk of inconsistency in information acquisition and processing, and therefore rely heavily on data traceability methods. For the participating citizens, it should also be ensured that the data protocol is easy enough to follow so that they are not deterred from the project. A more rigid protocol can result in higher quality data, while a more flexible protocol can give more freedom to participating citizens - but with a higher risk of low data quality (cf. Figure 2). An agreement should thus be sought among all stakeholders involved on the definition of (acceptable) data quality.

Figure 2: The balance between autonomous citizen science and rigid protocols[62].

Strictly speaking, data quality is referring to the correctness, accuracy and completeness of the data[63]. However, it is recommended that a more holistic approach is taken, and that aspects of data contextualisation (communicating about the context in which data and information were created), data reuse (clarifying data ownership and using open standards) and data interoperability (ensuring unproblematic reuse)[64] are also looked into. These three factors all have an influence on the data accuracy of your project.

Overall, it must be stressed that issues related to data quality are not unique to citizen science. In more conventional science methods, the replicability and reliability of the research results can also be a hurdle. Furthermore, studies also show that the quality of the data in citizen science research is more likely to be determined by the study design, the methodological approach and communication skills, rather than the citizen engagement approach per se[65].

In order to ensure the data quality in your research (project), there are several mechanisms that you can set up during or after the generation of data[66,67]:

- **Pre-test your data protocol:** Before launching your citizen science campaign, it is advised that you thoroughly test your protocol. As such, you can identify errors in measurements and ameliorate the design. It also helps you to spot the types of errors participating citizens can make, and maybe even to investigate ways you can rate or reward a good quality contribution of a citizen. It is best to display examples or errors anonymously without embarrassing anyone.

62 Veeckman, C., Van Herck, B., Carpentier, M., Van Laer, J. & Sterken, M., (2021). Citizen Science Roadmap for Local Government. A hands-on manual for citizen science, by and for cities and towns. SCIVIL, Leuven, Belgium.
63 Veeckman, C., Van Herck, B., Carpentier, M., Van Laer, J. & Sterken, M., (2021). Citizen Science Roadmap for Local Government. A hands-on manual for citizen science, by and for cities and towns. SCIVIL, Leuven, Belgium.
64 Balázs, B., Mooney, P., Nováková, E., Bastin, L., & Arsanjani, J. J. (2021). Data quality in citizen science. In: K. Vohland et al. (eds.),The Science of Citizen Science, 139. https://doi.org/10.1007/978-3-030-58278-4_8
65 Kaartinen, R., Hardwick, B., & Roslin, T. (2013). Using citizen scientists to measure an ecosystem service nationwide. Ecology, 94(11), 2645-2652.
66 Veeckman, C., Van Herck, B., Carpentier, M., Van Laer, J. & Sterken, M., (2021). Citizen Science Roadmap for Local Government. A hands-on manual for citizen science, by and for cities and towns. SCIVIL, Leuven, Belgium.
67 John Tweddle, Lucy Robinson, Michael Pocock & Helen Roy, Guide to Citizen Science. Developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK. (UK-EOF, 2012)

- **Training of participating citizens:** First of all, training can help to teach citizens how to collect, process or analyse the data. Clear step-by-step descriptions will help them to improve their scientific literacy and to perform the task in a good way. Training can be organised face-to-face or through online tools and platforms, e.g. manuals, FAQ, tutorial videos, etc.

- **Data validation:** Data validation mechanisms ensure that the data meet certain criteria and can therefore be used or analysed. For instance, validation checks in surveys that ensure that you write the data or a postcode in the correct format.

- **Data verification:** Next, the data submitted by citizen scientists can be checked and verified in collaboration with more experienced citizens, or by researchers. This can be done for the whole dataset, or only for randomly chosen samples of the dataset. On the Doedat platform (Dolt) of the Meise Botanical gardens, the scientists are verifying the data themselves. They still consider this way of working to be more efficient than when they have to make the observations without the help of citizens. Nowadays, you can also use software-based systems (based on artificial intelligence) that automatically identify outliers.

- **The law of large numbers:** Ensuring a large number of samples or observations, or involving citizens in a measurement on multiple occasions, can ensure better data quality. You collect a larger amount of data on which you can make statistical corrections. With a large amount of data, you can also have duplicates, which can help you check the accuracy of the results. For instance, the Curious Noses project involved a large number of citizens in the measurement of NO2. All participating citizens received two measuring tubes, which were installed at the same time. If the two measurements did not match, then the complete sample was excluded from the database and regarded as not reliable.

- **Systematically divide an area into segments or keep track of the sample frequency:** If applicable, it is also recommended that the periods and locations of observations are selected carefully. In order to make valid statements, it is best to systematically cover different types of areas in all seasons. For instance, Spinicornis maps the distribution of woodlice by dividing the Belgian territory into segments. They organise multiple field trips to each of those segments in order to systematically cover all seasons.

SUMMARY

Although there is a certain distrust and scepticism towards citizen-generated data, citizen science can provide high-quality data - similar to more conventional methods. If the research (project) has a well-designed protocol and quality assurance in place, then the data can be used for both scientific and policy objectives.

Reading tips:

- The data charter for citizen science (available in Dutch and English) can help you with further questions on data quality. This data charter is published by Scivil, the Flemish Knowledge Centre on Citizen Science, in collaboration with Digitaal Vlaanderen.

- You can read more about the usage of citizen science data for environmental monitoring in policymaking in this best practices report of the European Commission. It lists opportunities, challenges and potential benefits for policy uptake.

- This article by Fritz et al. (2019) presents a roadmap about how citizen science data can be used as an alternative source for measuring the United Nations Sustainable Development Goals.

- This study by Lovell et al. (2009) illustrates the effectiveness of participating citizens for sampling terrestrial savanna invertebrates in comparison to professional researchers. The results of the study show that there was little difference between the two samples, and that appropriate training helped to improve the validity of the data

- In this article by Feitag et al. (2016), additional mechanisms and strategies are described for ensuring good data quality.

Share your thoughts and opinions - Time for reflection:

- To what extent are you having concerns or distrust towards the usage of citizen-generated data in your research?
- How would you deal with participating citizens that have a particular agenda and who might cause significant bias in the data?
- Would you prefer to set up a peer review (i.e. by expert citizens) or an expert review of the data? What are potential challenges and benefits?

3.4. CITIZEN SCIENCE PLATFORMS FOR DATA MANAGEMENT

Nowadays, digital platforms offer great support for the collection, analysis and visualization of citizen science data. When you start to plan your research (project), you need to reflect on whether you need any technological support and, if so, which type of platform or tool is the best suited. The technological requirements will be greatly determined by your budget, your data protocol (cf. Module II) and the project goals. In determining these requirements, you also have to account for the sustainability aspects of your data: in which format will you publish the data, and for how long can the information remain available? Make sure that you also know how to deal with certain technological challenges[68], e.g. are citizens able to collect data in areas that are out of service, is the technology easy to use, and how will the platform be maintained in the long run?

The success of your research (project) will be determined by all these technical choices. It has been proven that data management via digital citizen science platforms can ease the interaction and communication between researchers and citizens, and can be cost-effective and time-efficient[69]. Furthermore, it can also be a motivational trigger for citizens to use and discover new technologies. However, digital technology does not always have to be the answer. Sometimes, using pen and paper might be the best solution, when automated observations pose privacy concerns for example.

CASE STUDY: MUIDE MEULESTEDE MORGEN (MUIDE MEULESTEDE TOMORROW IN GHENT, BELGIUM)

Measuring instruments do not have to be high-tech. You can just as easily collect traffic data using only pen and paper. This method of pegging was applied in the 'Muide Muilestede Morgen' project. This urban renewal project has an eye for sustainable mobility. A number of residents raised the issue of the excess amount of through traffic at the Muidepoort.

More information: https://stad.gent/nl/muide-meulestede-morgen

In contrast, the most advanced measurement technology involves **sensors**: there are hundreds of different types available, and it is often difficult to see the wood for the trees. There are sensors in all price ranges, from simple devices costing a few euros to professional set-ups costing thousands of euros. In order to solve your scientific problem, it is best to first ask yourself what a sensor must be able to measure - and with what degree of precision and accuracy. At the request of the 'Agentschap Binnenlands Bestuur' (Agency for Internal Affairs) of the Flemish government, a market analysis was performed by the consultancy company PwC on the available sensors that can be used for citizen science. Based on the research domain and the challenge, a list of sensors has been made available for consultation, together with a how-to guide. In line with open science principles, it is recommended that open hardware and low tech are preferred, or do-it-yourself solutions from this list.

68 Liu, H. Y., Dörler, D., Heigl, F., & Grossberndt, S. (2021). Citizen science platforms. In: K. Vohland et al. (eds.), The Science of Citizen Science, 439. https://doi.org/10.1007/978-3-030-58278-4_22

69 Capdevila, A. S. L., Kokimova, A., Ray, S. S., Avellán, T., Kim, J., & Kirschke, S. (2020). Success factors for citizen science projects in water quality monitoring. Science of the Total Environment, 728, 137843.

You can also decide to make use of **online platforms** and applications. Citizen science platforms are web-based infrastructures with one single entrance point[70]. These platforms offer an overview and search function of active citizen science projects, often in combination with guidance and support materials. They can be categorized into (non-)commercial platforms, and platforms for specific projects or specific topics, either nationally or globally bounded.

Citizen science platforms have the advantage that most of them already have an established community base, and that they are well managed by the initiators. Online platforms like Zooniverse or 'DoeDat' (Dolt), offer a wide range of activities that can be performed by the participating citizens, often along with some community features (e.g. comment section, personal track records, blogposts, etc.). You can upload your dataset or raw data on these platforms and ask citizens to analyse those data. This often involves annotating images, making classifications or transcribing texts. With online platforms like these, you make use of the software behind the platforms. You offer your information or data, and you remain the owner of the analysed data afterwards. The results of the analyses of the citizen scientists are delivered in an open format (e.g. CSV-sheet). Of course, you can also develop your own platform or tool for data collection, analysis or visualisation. This could be based on open-source code, such as OpenStreetMap, or on request by a private company. Make sure that you have sufficient budget available for supporting these activities, and that they are pretested for their user-friendliness.

Tips for building your own application or platform:[71]

If you want to build an application or platform yourself, you should not underestimate the costs. Several online tools allow you to make a rough calculation of development costs for mobile apps: App Development Cost, Buildfire, Digitalya. You can build a citizen science application using these online tools; some of them are free while others are paid:

- Natural Apptitude (for ecology and conservation)
- Open Data Kit
- Siftr
- Spotteron
- Arcgis Developers
- https://five.epicollect.net/
- https://www.citsci.org/ (for data collection and visualisation)
- The citizen science project builder of the Citizen Science Centre Zurich
- https://www.ushahidi.com/ (for crowdsourcing)

The following citizen science platforms can be used for data collection, analysis or visualisation; they are all entry-level:

- The Zooniverse is an international platform for the annotation and transcription of datasets, and includes more than one million interested citizen scientists worldwide. If you would like to run your project on Zooniverse, you will have to apply to the platform. In the project builder section, you can upload your datasets and choose the tasks you want the volunteers to do.

- DoeDat (Dolt) is the online crowd sourcing platform of the Meise Botanical Gardens, on which citizens can digitise their herbaria. The purpose of this crowdsourcing platform is to help the Meise Botanical Gardens to digitize their collections and to give citizens the chance to play an active part in this process. You can also post your project on the 'DoeDat' platform if it fits within the themes of the platform. For instance, Luca Schools of Arts has a project 'Flemish and Dutch flower still lifes from the 16th and 17th century'. The participating citizens are invited to describe the images as accurately as possible.

- iNaturalist is an international application and online community through which citizens help to identify plants and animals. You download a mobile application, take a picture via the application, and you upload it to the community. The Dutch variant of this platform is https://waarnemingen.be/ by Natuurpunt, Natagora and Stichting Natuurinformatie. Here, you also download a mobile application to upload your observation. Automatic image recognition helps to identify the species or animal.

- MijnTuinlab (MyGardenLab) is a Flemish platform which collects citizen science projects that can be run in your own garden. It is an initiative of Natuurpunt, Kenniscentrum tuin+ (Erasmushogeschool) and KU Leuven. Examples of projects are FlowerPower, Spin-City, Weekly Bird Count, etc.

70 Liu, H. Y., Dörler, D., Heigl, F., & Grossberndt, S. (2021). Citizen science platforms. In: K. Vohland et al. (eds.), The Science of Citizen Science, 439. https://doi.org/10.1007/978-3-030-58278-4_22

71 Veeckman, C., Van Herck, B., Carpentier, M., Van Laer, J. & Sterken, M., (2021). Citizen Science Roadmap for Local Government. A hands-on manual for citizen science, by and for cities and towns. SCIVIL, Leuven, Belgium.

- 'Vele Handen' (Many Hands) engages citizen scientists in the transcription of historical, often handwritten, documents. 'VeleHanden' is a crowdsourcing platform of Picturae. Picturae is a Dutch enterprise active in digitizing and opening up heritage collections for museums, archives and libraries at home and abroad.

- The BiodivERsA citizen science toolkit lists more useful tools and applications for biodiversity researchers.

Lastly, the following platforms can be used for listing and promoting your research (project) to citizens:

- SciStarter is an international platform which disseminates your project to a community of citizen scientists. SciStarter allows citizen scientists to track and earn credit for their contributions to science projects. They also offer some training modules.

- The Dutch-speaking platform for citizen science is "Iedereen Wetenschapper" (Everyone's a Scientist). You can submit your project to the website www.iedereenwetenschapper.be. If your project satisfies the conditions, they will send out a standard questionnaire and the editor at Everyone's a Scientist will post your project to the platform. Your project is published on the platform freely, and it is mentioned in the monthly newsletter and on the Everyone's a Scientist social networking site. They also offer paid services for editing texts, helping with recruitment strategies, etc. The platform does not offer any collection or analysis options.

- Lastly, you can also promote your project on the Eu-Citizen.Science platform.

SUMMARY

Defining the technological requirements for your research (project) can be a challenging task. If possible, we recommend leveraging upon existing open-source platforms and tools. Nowadays, many solutions are already available which offer data collection and analysis options, often with an already established community of citizen scientists. If existing solutions do not fit, you can develop your own measurement devices, or rely on private companies that develop these solutions.

Share your thoughts and opinions - Time for reflection:

- Do you have any tips about using (low-cost) sensors for environmental monitoring? How do you balance the trade-off between data accuracy and the cost of the sensor?

- What are your experiences related to citizen science platforms for networking purposes?

- Can you recommend any other platform or mobile application for citizen-generated data collection or analysis?

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