European Commission

MUTUAL LEARNING EXERCISE

Citizen Science Initiatives - Policy and Practice

First Thematic Report:
Introduction and Overview on Citizen Science

PSF CHALLENGE

HORIZON EUROPE
POLICY SUPPORT FACILITY

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Report

Research and Innovation

Mutual Learning Exercise on Citizen Science Initiatives - Policy and Practice
First Topic Report: Introduction and Overview on Citizen Science

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Mutual Learning Exercise on Citizen Science Initiatives - Policy and Practice

First Topic Report:

Introduction and Overview of Citizen Science

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LIST OF ABBREVIATIONS

CAISE: Center for Advancement of Informal Science Education
CS: Citizen Science
CSI-PP: Citizen Science Initiatives – Policy and Practice
DG: Directorate-General
DGD: Belgium Development Corporation
DITOs: Doing it Together Science
DIY: Do-It-Yourself
EC: European Commission
ECSA: European Citizen Science Association
EEA: European Environment Agency
EFTA: European Free Trade Area
ERA: European Research Area
ERC: European Research Council
EU: European Union
FET: Future and Emerging Technologies
FP: Framework Programme
ICT: Information and Communication Technology
IIASA: International Institute for Advanced Systems Analysis
ISCED: International Standard Classification of Education
JOGL: Just One Giant Lab
KIP: Key Impact Pathways
MLE: Mutual Learning Exercise
MUST: Mbarara University of Science and Technology
OPAL: Open Air Laboratories
OSPP: Open Science Policy Platform
PAR: Participatory Action Research
PPSR: Public Participation in Scientific Research
PSF: Policy Support Facility
R&I: Research and Innovation
RBINS: Royal Belgian Institute of Natural Sciences
RMCA: Royal Museum for Central Africa
RPO: Research Performing Organisations
RRI: Responsible Research and Innovation
RSPB: Royal Society for the Protection of Birds
STEM: Science, Technology, Engineering, and Mathematics
UK: United Kingdom
UNESCO: United Nations Educational, Scientific and Cultural Organization
WCG: World Community Grid

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FORWARD

This document has been prepared under the auspices of the Policy Support Facility (PSF) set up by DG Research and Innovation to provide practical support to Member States on specific and operational Research and Innovation (R&I) challenges that they have expressed interest in addressing. The practical support, independent high-level expertise, and guidance offered by the PSF Challenge service aim to identify good practice, lessons learned and success factors for participating Member States and Associated Countries.

This report is the first in a series within the Mutual Learning Exercise (MLE) on 'Citizen Science Initiatives - Policy and Practice' (CSI-PP), which commenced in December 2021.

The purpose of this MLE is to facilitate the exchange of information, experience and lessons, as well as to identify good practices, policies and programmes in relation to varying approaches at local, regional and national levels, towards supporting and scaling up citizen science. An additional objective is to identify citizen science campaigns that have high potential to be implemented in a collaborative way across the European Research Area (ERA).

The role of Citizen Science (CS) in supporting R&I in the European Union (EU) has been growing in the past years. Starting with the 2014 White Paper on Citizen Science1, which rolled out a strategy for a substantial increase of the use of Citizen Science and practice in support of scientific advances, the attention given to the potential of CS for Member States and the EU has been increasing. A clear example is the incorporation of CS as a core dimension of the new ERA. The 2020 Commission Communication stated that engagement of citizens, local communities and civil society will be at the core of the new ERA to achieve greater societal impact and increased trust in science.2 and the 2021 Council Recommendation on a "Pact for R&I in Europe" lists "active citizen and societal engagement in R&I" as a priority area for joint action in the EU.

The Horizon Europe Programme also aims to "engage and involve citizens and civil society organisations in co-designing and co-creating responsible research and innovation agendas and contents, promoting science education, making scientific knowledge publicly accessible, and facilitating participation by citizens and civil society organisations in its activities".3

This PSF MLE responds to the request submitted by the Trio Presidency of Germany, Portugal and Slovenia, and eleven countries are participating (Germany, Portugal, Slovenia, Austria, Belgium, France, Hungary, Italy, Norway, Romania and Sweden). The MLE will be structured in five rounds of meetings on specific topics that have been pre-identified by the participating countries. This first report presents the first topic: ''Introduction and overview on citizen science''.

[1] Serano Sanz et al. 2014

[2] European Commission, 2020 COM(2020) 628 final.

[3] European Commission, 2018 COM(2018) 435 final.

1. Introduction

1.1 The role of citizen science in research & innovation

European society is more educated and connected than ever before, enabling many more people to take an active part in a wide range of R&I activities. In the past, people were mostly limited to observing nature and recording their observations in private notebooks, building a private niche knowledge of their own area. Today, as they take a picture on their phones and share it using the Natusfera app[4], they are not only learning about species themselves, but their images are joining a global database of nature observations that allow scientists to analyse biodiversity trends at a level of detail that was unimagined even just a decade or two ago (Figure 1). Moreover, the images and the annotations by volunteers can be used as a basis for machine learning algorithms, thus helping novice observers to see a likely species identification for an image that they submit to the system. Not only does this system demonstrate a productive collaboration of humans and machines in knowledge production, it also serves to educate a new generation of nature observers, as well as to create datasets that are critical for the movement towards the green economy.

Citizens with a more specialist background engage in bottom-up initiatives as volunteers. For example, life science volunteers came together on the Just One Giant Lab (JOGL) platform that is run from Paris. During the Covid-19 pandemic they explored collaborative innovations that they could offer to help address the social emergency[5].

It is, therefore, unsurprising that this active participation in R&I, which is nowadays termed "citizen science", has received much attention. It is flourishing under different names and different formats, across all scholarly fields - from physics, earth sciences, and biology, to medical research, the humanities and the social sciences. The attention for public engagement in R&I is also integrated into current concepts in science policy. Within both the UNESCO and the European Union formulation of Open Science, citizen science is seen as one of the core pillars.

To deliver on its full potential, the response to citizen science by R&I actors, such as national government science and innovation decision makers as well as research funders, is of particular importance. This MLE is aimed at understanding citizen science initiatives from a science and research policy perspective.

[4] Piera et al. 2016

[5] Franzoni et al. 2021

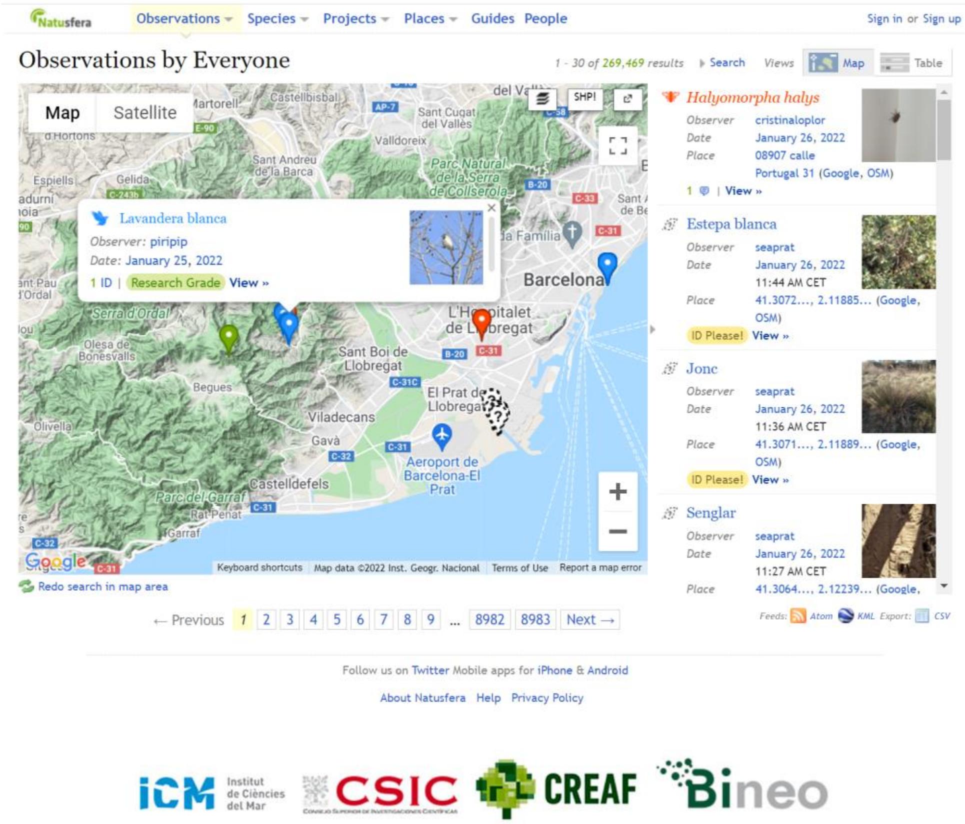

Figure 1: Natusfera app with a recent observation near Barcelona.

1.2 Scope of the Report

This first report within the MLE-CS series of Thematic Reports introduces the overarching topic of citizen science, with an overview of the landscape and state of play for citizen science across Europe, to set the foundations for the MLE Challenge topics to follow.

Each report is led by the expert for that topic and supported by the rapporteur and the other experts engaged in the MLE Challenge. The next reports in the series will be prepared following the online meetings or country visits that take place on that topic, and will summarise and present the good practices, lessons learned and success factors identified during those meetings, supported as far as possible by robust evidence on the impact of those measures.

However, in the case of this first report, Covid-19 travel restrictions and health considerations moved the first meeting of the MLE online (on 18th and 24th January 2022) and shifted the focus to the laying of a good foundation for the remainder of the MLE. During the two online sessions of three hours each, MLE participants shared information in a more limited and compact fashion than otherwise would have been possible. The core purpose of this report is thus to establish a shared understanding of citizen science that can be carried throughout this exercise, by describing the characteristics and principles of citizen science, showcasing a range of ways in which citizens interact and engage with science, and presenting how citizen science is currently being promoted through EU and national funding mechanisms. It also provides more information about the context and Modus Operandi of the MLE.

1.3 Outline of the Report

The structure of this report thus consists of:

- **Section 2**: Introductory overview of citizen science, practical examples from Member States
- **Section 3**: How citizens interact and engage with science, and where citizen science fits within the wider area of science and society
- **Section 4**: The characteristics and principles of citizen science
- **Section 5**: How citizen science is promoted through EU and national funding mechanisms
- **Section 6**: Next Steps within the MLE and Modus Operandi

Within these sections, we provide several case studies of citizen science projects that are demonstrating some of the issues identified in this report. As the first meeting was originally planned to be hosted by Belgium, we focus on examples from institutions and research activities within this country, namely:

- The air quality Flemish project Curieuze Neuzen
- Royal Belgian Institute of Natural Science (RBINS) XperiBird project
- Royal Museum for Central Africa (RMCA) snail-borne disease vectors project
- Scivil – knowledge centre for citizen science in Flanders
- Brussels Co-Create Support Centre

2. A brief introduction to citizen science

2.1 A spectrum of activities and practices

Citizen science is both old and new. The involvement of non-professional scientists in scientific research in Europe predates modern science, which emerged in the middle of the 16th century. In fact, well into the scientific revolution and the 18th century, science was a side activity of wealthy and educated (mainly male) elites. Only with the advances of the 19th century did the profession of full-time scientist become more common - the term “scientist” itself was not introduced into the English language until the 1830s. The development of science as a profession with people employed for the sole purpose of doing science resulted in a separation between professional science and the rest of society, including amateur scientists. Fast forward to today, and we need to reconsider how to relink society and active participation in science. This leads us to consider and highlight the ongoing importance of public participation in scientific research (PPSR) as a way to re-establish these forgotten links.

Moreover, there are plenty of areas of scientific research where non-professionals never ceased to play a role (see 'long-running citizen science' in Figure 2). By understanding the factors that explain the continued role of non-professionals, we can gain insights into the value of citizen science. In many areas of ecology and biology, volunteers contributed to observations and collaborated with scientists, natural history societies and museums. In fact, one of the origins of the term citizen science emerged from ornithologist Rick Bonney's observation that in the field of ornithology, public participation is inherent and necessary[6]. The need to cover very large areas and collect multitudes of records means that it is not possible to carry out such research with the traditional scientific methods, it is necessary to work together with amateurs and volunteers.

Weather observations and measurements also depend on a dense spatial and temporal network of observers, necessitating the participation of non-professionals. For example, the Austrian "Trusted Spotted Network'' involves volunteers reporting on significant and severe weather events, following strict and detailed guidelines. This is also the case in the humanities, for the compilation, sharing, and transcription of local historical archives. One example of this is the Fortepan project in Budapest, Hungary, which collects and shares photos from before 1990 in an openly accessible database that consists almost entirely of original photos taken and collected by citizens on building sites and in the streets of Budapest. It now serves as an important primary source for historians, sociologists and other researchers. Archaeology and astronomy are other areas where volunteers have continued to play an active role over the decades, and indeed centuries.

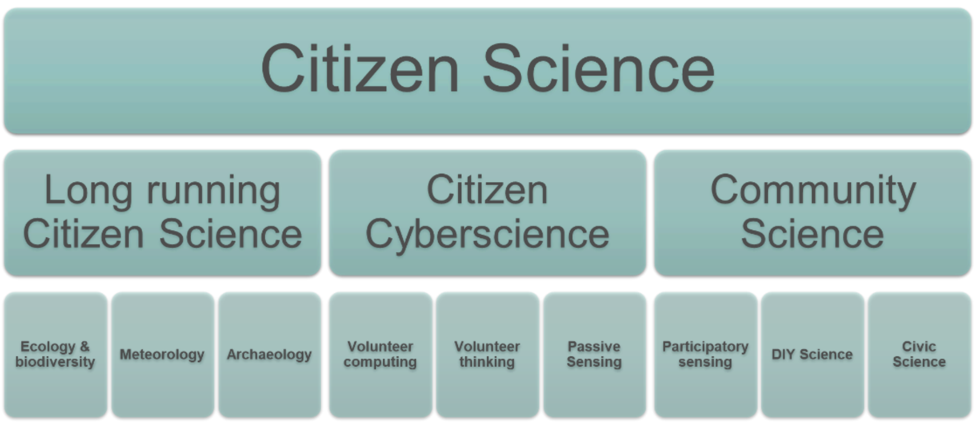

Figure 2: Different forms of citizen science (after Haklay et al. 2018)

Technological advances and the increase in public knowledge and skills (see section 3) have changed the way that people can participate in projects - if in the past a birdwatcher that participated in an ornithology project would send a postcard with observations, nowadays they can use an app such as eBird and the observation will become instantly part of an international observation database.

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[6] Bonney 1996

These technological developments have enabled new types of citizen science activities that can be grouped under the heading "citizen cyberscience" - a term that was created to describe activities that rely on the use of computers and the internet[7]. As shown in Figure 2, citizen cyberscience includes activities such as volunteer computing, where participants donate the unused computer processing power of their devices to scientific calculations. These can be a desktop computer, a laptop, or even a smartphone. For example, the Vodafone Foundation supported Dreamlab, a project that allows people to donate spare processing power to processing tasks in support of scientific missions, such as the analysis of drugs and food that can help in addressing the Covid-19 pandemic (Figure 3).

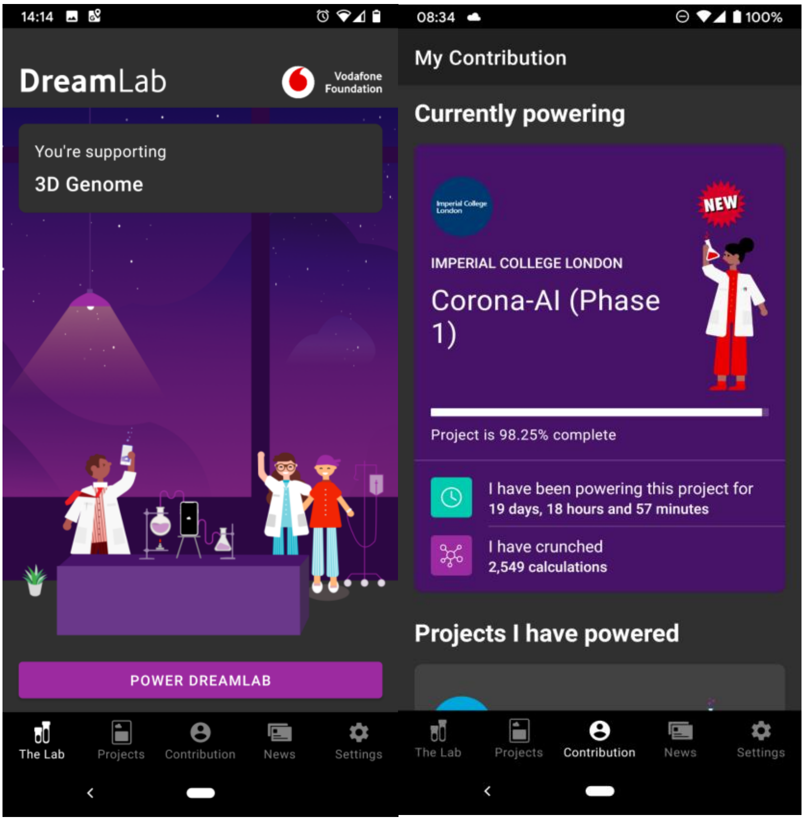

Figure 3: Dreamlab interface on mobile device

A second type of activity within citizen cyberscience is volunteer thinking. This is a very common form of participation in citizen science, and it engages volunteers at a more active cognitive level. In these projects, participants visit a website on which information or an image is presented to them. They are provided with a training walk-through of the task for classifying the information, typically with a practical session, after which they are introduced to information that has not been analysed and are asked to carry out further classification work. An example of this activity is PicturePile, which was developed by the International Institute for

[7] Grey 2009

Advanced Systems Analysis (IIASA) in Austria. PicturePile[8] asks participants to help classify large datasets of images by carrying out simple classification tasks (e.g., noting how many floors a building has). This can support the creation of datasets that will be used for machine learning. One of the best-known web platforms for this type of activity is the Zooniverse[9], which was originally developed for the crowd-classification of astronomical images, but now supports activities in domains as wide ranging as zoology, the humanities, and medicine.

The final type of citizen cyberscience activity is passive sensing, in which participants either connect sensors to their computers or use the built-in sensors that are available in smartphones. Passive sensing is mostly based on automatic data capture and sharing, without the conscious intervention of the volunteer, and therefore more closely resembles volunteer computing, while on the move. For example, in a BBC Contagion! programme in 2018, participants were asked to download an app and switch on their bluetooth. This enabled researchers to model the spread of a highly contagious pandemic, and the resulting model was used in the early stages of the Covid-19 pandemic[10] within the UK response.

A third grouping of citizen science activities, alongside long-running CS and citizen cyberscience, fall under the heading "community science". These are projects that involve a higher degree of initiative and control from the participants themselves. They usually emerge when a community of people with a shared interest, location, or experience come together to address an issue that they are facing. Such a community can be a community of place which experience an environmental nuisance (e.g., concerns about air quality), or a community of patients with a rare condition, which they feel is neglected or not addressed by the professional medical community.

In both traditional and cyberscience projects, scientists are leading the project and identifying the problem that will be addressed, with participants carrying out a specific (and frequently limited) task. In contrast, community science projects follow a mode of co-production, in which the project is planned and executed by collaboration of scientists with community members. Sometimes the project is completely initiated and led by community members themselves, with limited or no involvement of professional scientists. Here we can find Do-It-Yourself (DIY) science such as the Covid-19 tracker project in Slovenia[11] where a group of people with expertise in data science and data management created a website for the monitoring of the evolution of Covid-19 in their country. Participatory sensing activities are projects that involve the use of sensors where community members decide where to deploy them. Common examples of these include air quality or noise pollution monitoring at the local level, such as the CurieuzeNeuzen project in Flanders (see Box 1). In participatory sensing it is more common to see professional scientists with a significant role in the project.

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[8] https://previous.iiasa.ac.at/web/models/picturepile/Picture_Pile.html
[9] https://www.zooniverse.org/projects
[10] Klepac et al. 2018
[11] https://covid-19.sledilnik.org/en/about

Box 1: CurieuzeNeuzen – Curious Noses

The CurieuzeNeuzen project started in Antwerp in 2016 as a community initiative to monitor air quality using a simple device – a diffusion tube. This passive device, used since the 1970s, records the average level of pollutant presence in the ambient air. A tube is left in place for a period of time and then provides an indication of the level of pollutants, such as nitrogen dioxide (NO2). After the community initiative in Antwerp, the project grabbed the attention of professional researchers and a national newspaper, and in 2018, over 20,000 households across Flanders (the northern region of Belgium) participated in the Flemish edition of CurieuzeNeuzen.

Citizens measured the air quality near their own house during the month of May 2018 by putting two diffusion tubes, placed within a v-shaped window sign commonly used for advertising a flat or house sale. The window signs, which also promoted the project (see Figure 4), were placed on a street-facing window of their house, apartment or building. The two diffusion tubes were then used to assess the mean concentration of aerosol pollutants throughout the month.

The data collected was quality controlled and calibrated with NO2 measurements at reference monitoring stations operated by the Flemish Environment Agency (VMM), and the results produced a very fine detail of the level of pollution across Flanders. The aim of the project was to acquire a highly detailed map of air quality in Flanders, both in cities as well as in the countryside. CurieuzeNeuzen Flanders is the largest citizen science project on air quality to date in terms of the number of people that were involved in it.

Interestingly, the results challenged some of the models developed by VMM, and therefore the results from the project allowed the optimisation of these models. The dense sampling design also revealed the presence of so-called ‘street canyons’, where the European pollution norm was exceeded.

CurieuzeNeuzen was successful in putting the topic of air quality higher on the political agenda in Flanders, to strengthen air quality monitoring and set higher ambitions in action plans to address air pollution problems at local level. The project was also successful in creating awareness on the topic in broader society. The Flemish Air Policy Plan 2030 directly references CurieuzeNeuzen and that the VMM will use this experience to further support citizens and local governments in measuring air quality and organising citizen science projects (source: CurieuzeNeuzen website).

Figure 4: Curieuze Neuzen Flanders installation in May 2018 (Source Spotter2, Wikimedia Commons)

In summary, this overview of activities highlights the need for a pluralistic understanding of what citizen science is. The need for plurality is arising especially when we consider how citizen science is integrated across disciplines. Even this brief and partial overview demonstrates a wide range of cognitive engagement, links to action, areas of research, and use of technology.

The disciplinary differences are especially important, since what is considered high quality research for local historical studies is very different from the collection of bird nesting data in ornithology, or the strong affinity for randomised control trials as the "gold standard" in medical research. As a result, designing and implementing citizen science within R&I policy must allow the adaptation of the details of citizen science to the specific context and practice of the domain of science.

2.2 A range of goals in citizen science activities

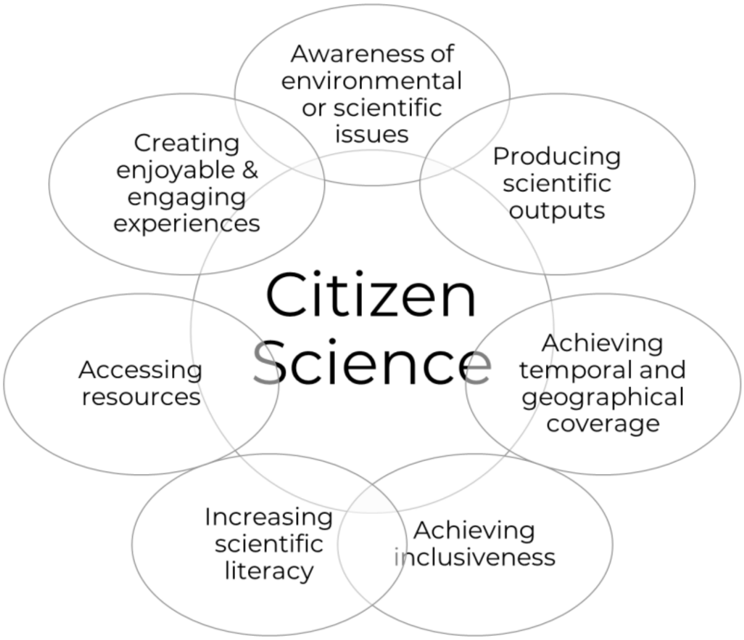

Figure 5: Some of the goals that are associated with citizen science projects

Another important way to understand the plurality of citizen science activities is to look at the expectations placed on them in terms of outcomes and impacts. A traditional scientific research project used to lead to a limited number of outputs and outcomes, such as academic papers or posters, and perhaps over time new innovations. Nowadays the expectations placed on research projects, alongside publications that describe the findings (ideally open access), also include addressing the problem to which it was set, training people that are involved in the project with technical and scientific skills, and sharing the results more widely beyond academia. Although links between research projects and policymaking are notoriously difficult to prove, an expectation for such impact can also be expected from academic research.

In citizen science, in addition to these scientific goals there are multiple additional goals that come into play (Figure 5), and for each project there may be a multiplicity of expectations set. Such goals, from the perspective of scientists and funders may include raising public awareness to the scientific issue underlying the project, production of scientific knowledge and outputs, ensuring a sampling methodology, or facilitating the geographical and temporal coverage at scales that are impossible otherwise. Projects might be expected to be inclusive in terms of gender, ethnicity, educational attainment, and increase scientific literacy, while also finding ways to access people's resources (e.g., time) and create an enjoyable and engaging experience. An example of such a project with plural goals is XperiBIRD.be (Belgium), presented in Box 2.

Balancing these different goals is challenging. For example, if a project aims to reach out to under-represented groups while producing high-quality scientific results, it will require the recruitment of staff that can reach out to such groups and invest significant resources in outreach - this might include purchasing devices and telecommunication contracts for participants. On the other hand, a project that aims for a very wide public outreach and rapid scaling up, might need to compromise on inclusion and spend more on mainstream media communication channels and communicators (an issue that will be addressed in topic 5 of the MLE). This can also happen when the science methodology that is used requires a specific scale of sampling to provide enough statistical power.

Furthermore, in citizen science, there is a need to consider the goals from the perspective of the participants. For example, addressing a local pollution issue, or ensure better quality of life for participants and citizens at large. Such a reason for participation can be seen in CurieuzeNeuzen (Box 1) in their wish to provide information that can help the authorities address air quality, or in the ATRAP project (Box 3) addressing a disease that is inflicting their community. This consideration of goals for all stakeholders (scientists, funders, and participants) creates richness as well as challenges.

The need for identifying the scientific and social goals of the project are important in any scientific project. However, when considering a citizen science project there is a need to carefully consider the trade-offs. Especially within R&I programmes and funding, it is worth explicitly articulating what these goals are and how they will be achieved. Logic models are a particularly well-suited tool for this when adopted for citizen science projects, to provide a way to explicitly define the paths from funding to achieving goals (for an example from the Horizon 2020 programme see Skarlatidou and Haklay 2021[12]). Logic models analyse the short- and long-term outcomes from a project and consider how the resources and activities that are part of the project can lead to the outcomes.

Box 2: The XperiBIRD engagement and citizen science tour

Case provided by Carole Paleco, RBINS

XperiBIRD.be is an educational and citizen science project set up through the partnership between the Royal Belgian Institute of Natural Sciences (RBINS) and Google.org. It aims to distribute nest boxes equipped with a camera controlled by a nano-computer (Raspberry pi) to schools and educational partners across Belgium. The observation kit allows children from primary and secondary schools to follow the nesting of garden birds such as great or blue titmice.

The objective of this activity is to stimulate their interest in sciences and new information technologies and to collect a large amount of data on the nesting habits of passerine birds across Belgium. Those data are then being studied by the ornithologists working at the RBINS.

The schools that have subscribed to RBINS science truck tour (XperiLAB.be) can ask for a nest box besides the visit of truck (see Figure 6). Between

[12] Skarlatidou & Haklay 2021

September 2016 and Spring 2019, a total of 607 nest boxes equipped with a camera were active across Belgium. It represents more than 47,000 students actively taking part in the experiment within the schools and about 23,500 participants educated thanks to non-profit organiations involved in the project. The kit is plug and play, and the observation kit enables the teachers to install the device themselves.

Figure 6: XperiBIRD equipment (source RBINS)

The observed data are collected and entered by the pupils and their teachers, using tutorials on the scientific method and data entering so that these can be analysed and used by scientists. The project showed an even interest among boys and girls of 10-14 years old activating as well some of the untapped potential for more STEM & ICT.

Two springs of observing 2017-2018 led to 148 broods belonging to 6 species of cavernicolous passerines monitored day-to-day, 1331 eggs counted, 1052 chicks hatched of which 790 successfully took flight[13]. In addition, through the RBINS Belgian ringing scheme, populations of birds can be monitored by the ringers coming at school and showing how to ring the young hatched in the nest box.

XperiBIRD demonstrates multiple goals in a citizen science project: providing education and awareness of an important ecological issue, reaching out to under-represented groups, exposing them to technology and data analysis and so on.

[13] RBINS 2018

2.3 Common typologies of citizen science activities

While Figure 2 provides an overview of the kinds of activities that can be found under the umbrella of citizen science, it does not provide a comprehensive typology that attempts to cover all the activities in the field. Because of the plurality inherent in citizen science, multiple typologies have emerged and a recent review identified 13 such typologies[14]. Here we highlight the two typologies that have carried more weight over time and are more widely used and referred to in the literature.

Although it has earlier origins, the most influential typology emerged from an inquiry in 2008 by the US-based Center for Advancement of Informal Science Education (CAISE). Their seminal report, led by Rick Bonney, on Public Participation in Scientific Research[15] developed a typology that looks at the relationships between scientists and participants in terms of control over the project and its outcomes. The typology includes three classes of projects (contributory, collaborative, co-created). An update for this classification is offered by Jennifer Shirk and her colleagues[16] with the addition of two further classifications (contractual and collegial) which covers two forms that are missing in the original. The later typology includes five types of projects that are all using a word that starts with C, so the model can be remembered as the "5Cs typology":

Contractual projects are projects in which members of the public approach professional researchers with a request to carry out a piece of research and report the results so those who commissioned it can use them to address an issue of concern. This involvement of researchers can be either pro bono (as in the model of science shops) or paid.

Contributory projects are projects that are designed and run by researchers, and then project owners invite and recruit members of the public to assist them in a range of tasks such as data collection, classification or transcription.

In **Collaborative projects**, the researchers design the project and invite participants to join the project, but participation is enabled across more stages of the research process. This can be done by engaging participants in the analysis of the data that was collected, or by refining the research questions, or data collection methodology, or by assisting in the dissemination of the results.

Next are **Co-Created projects**, which are designed by researchers and members of the public together. These projects require the scientists to accept the participants as peers in multiple stages of the research process.

Finally, **Collegial projects** are happening completely outside the common research setting, with people carrying out research independently with different

[14] Haklay et al. 2021
[15] Bonney et al. 2009
[16] Shirk et al. 2012

levels of communication and contact with professional researchers. DIY science projects are inherently collegial.

An illustration of a project that combines the contributory and collaborative approaches is the ATRAP project, presented in Box 3.

Box 3: Citizen science to monitor diseases and empower communities- ATRAP

Case provided by Tine Huyse, RMCA

The control of neglected tropical diseases necessitates an integrative approach combining drug treatment, targeted vector control, and community involvement. Citizen science has the potential to support and combine interventions by increasing monitoring capacity and public engagement at the same time. Indeed, contributory citizen science projects tap into the power of the crowd, generating high-resolution datasets while collaborative projects involve citizens in other stages of the project apart from data collection. This facilitates a two-way exchange between citizens and scientists.

The ATRAP project combines both approaches and is focused on neglected tropical diseases that are transmitted by freshwater snails. The project is a collaboration between Mbarara University of Science and Technology (MUST) in Uganda, the Royal Museum for Central Africa (RMCA) and the Katholieke Universiteit Leuven (KU Leuven) in Belgium, funded by the Belgium Development Cooperation (DGD). While liver fluke disease is already endemic in Europe, blood flukes (bilharzia) are predominantly found in Africa but re-emerging in Europe due to climate change and increased human mobility.

The overall aim of ATRAP is to reduce the incidence of snail-borne diseases by adopting a citizen science approach. It has two major objectives:
1) to generate accurate distribution maps of snail vectors to identify transmission hotspots and guide targeted snail control, and
2) to co-create awareness campaigns that focus on disease prevention.

Two networks of 25 citizen scientists each have been set up in Uganda and Congo[17]. They weekly monitor a fixed number of sites for snail presence and human water contact patterns. They identify the snails up to genus level, count and photograph them and upload the data using KoBoToolbox installed on their smartphone (see Figure 7). The same citizens have also co-designed interventions with the ATRAP partners, leading to community-led awareness campaigns. This allowed them to integrate local knowledge and experiences and develop contextualised communication tools. It is anticipated that this shared problem-solving increases ownership and agency, producing longer-lived results compared to top-down approaches[18]. A very similar approach is used in another project of the Royal Museum for central Africa to monitor

[17] Brees et al. 2021
[18] Ashepet et al.2021

environmental hazards like landslides: HARISSA[19].

Figure 7: Participants collecting snails that transmit diseases like bilharzia. Snail data and pictures are uploaded on the KoBo platform that can be accessed by researchers (source: RMCA)

Also focusing on the control over the project and influenced by ideas about levels of citizen participation in urban planning (such as those offered by Arnstein in 1969[20]) the Haklay classification[21] offers four degrees of engagement, starting with **crowdsourcing**. At this level, participation is done through provision of resources, with a minimal cognitive engagement — this includes volunteer computing and passive sensing.

Next is **distributed intelligence** that utilises the cognitive ability of the participants in observing, classifying, and analysing information but in a way that relies on basic training and a limited range of actions.

The third level, **participatory science**, is capturing action projects in which "problem definition is set by the participants and, in consultation with scientists and experts, a data collection method is devised. The participants are then engaged in data collection but require the assistance of the experts in analysing and interpreting the results." (Haklay 2013, p. 117).

[19] https://www.africamuseum.be/en/research/discover/projects/prj_detail?prjid=710

[20] Arnstein 1969

[21] Haklay 2013

Finally, **extreme citizen science** is similar to the collegial classification in the 5Cs classification. The decisions on what will be researched, the methodology of data collection, the analysis, and the interpretation are done by the participants with or without professional researchers.

In both typologies it is important to note that **there is no value judgement regarding a specific type of activity**. The different classifications should not be seen as putting a higher value on co-created projects or on extreme citizen science projects. As we will see in the next section, different people in different contexts may want to contribute to science in different ways. For example, contributory projects have the potential to reach millions of people, something that co-created projects would struggle to do. Projects can also alternate between different modes in different stages of the research or project journey. For example, CurieuzeNeuzen (Box 1) started as a collegial project and evolved into a contributory one. The selection of the mode of engagement needs to be aligned with the project goals as noted in section 2.2.

3. How citizens interact and engage with science

3.1 The educational transition as a driver for citizen participation[22]

When trying to make sense of the rapid growth of citizen science in the past decade, the development and expansion of mobile internet technologies are frequently noted. However, the remarkable transition that has happened in European and global society in terms of education and the capacity to take part in research has also played a large role in the growth of citizen science.

Over the past 30 years, the number of people with tertiary education has increased rapidly. UNESCO statistics show that in 1990, there were 68 million (M) students in higher education in the world. By 2000, this increased to over 100M, over 180M in 2010, and 235M in 2020. It is important to recall that when looking at the global workforce, on average a student will spend up to five years in tertiary education, and therefore this is reflected in rapidly educated societies. Even at the highest level of education (equivalent to PhD) we have seen a remarkable increase in the past 20 years - from 1.63M to 3.29M by 2020 (Figure 8).

Such transition means that the experience of studying in higher education is no longer the preserve of a small group within the population, but a common experience within the young cohorts of countries across the world, and in Europe in particular. While these changes impact the job market, and the type of economic activities that can be carried out by the population, they also have an impact on public engagement with science. The ability to read and interpret scientific information in the population at large has increased, and a notion of what is the purpose of scientific research is more common.

[22] This section is partially based on material that appeared in Haklay 2018.

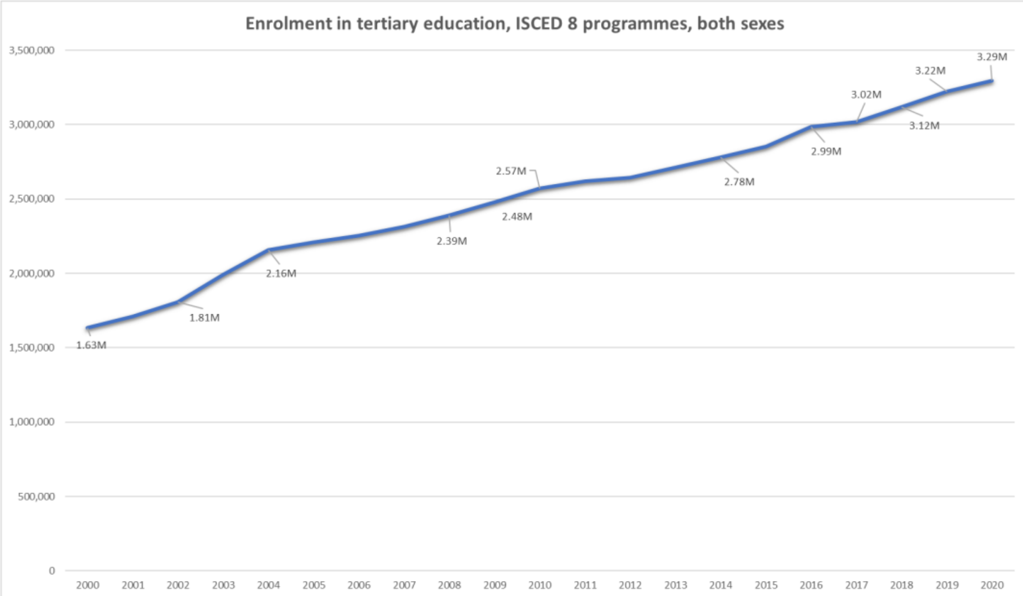

Figure 8: Number of students enrolled in PhD level programmes across the world (source UNESCO UIS)

When we examine European growth in tertiary education over the same period, it is much more moderate (Figure 9). Part of the explanation for the milder increase is that European society is highly educated already. However, the EU has set a target of 40% tertiary education attainment amongst the 25-34 age group within the population - a target which is not yet obtained. Again, it is important to note that because of the temporal nature of tertiary education, those who complete it, join the workforce with basic knowledge about science and research.

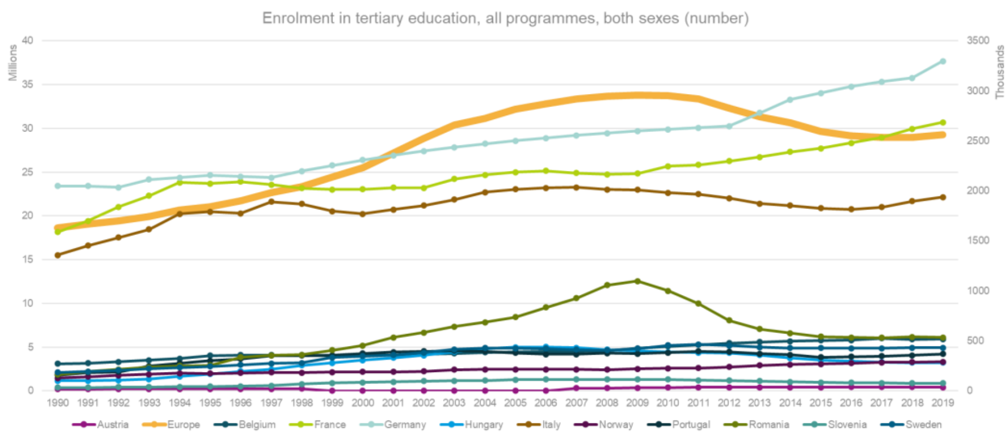

Figure 9: Tertiary education and enrolment in Europe and in the 11 Member States that participate in the MLE (source UNESCO UIS)

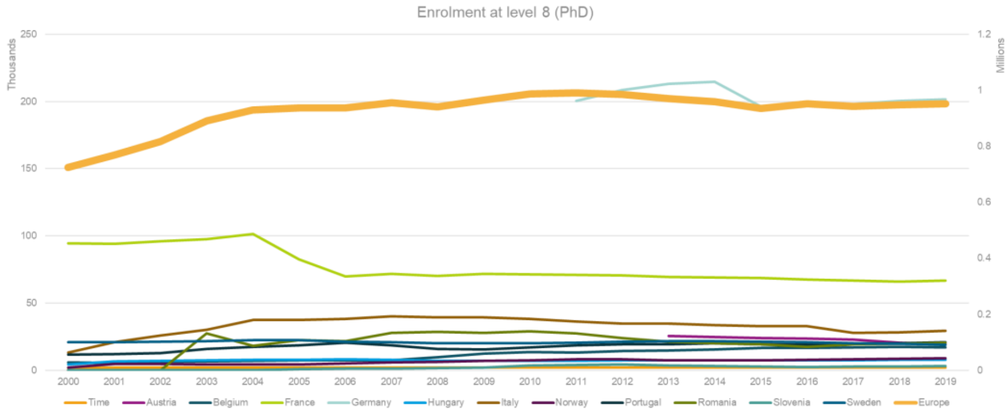

Figure 10: Tertiary education and enrolment at PhD equivalent in Europe and in the 11 Member States that participate in the MLE (source UNESCO UIS)

Yet, as Figure 10 shows, we can see a continual increase in higher level skills within European society. For example, the number of PhD students evolved from around 800,000 in 2000 to 1M in 2020. Because many of the papers examining citizen science demographics rely on data from the early 2010s, it is worth noting that according to Eurostat (2016), across the EU28 countries nearly 33% of the population aged between 25-55 has tertiary (university) education, and 20% of those above this age group also have tertiary education. This headline figure masks a wide variability based on the cultural and economic context of each country. For the 25-55 age group, the UK was at 43.8%, Spain 38.4%, France 38%, Poland 32.7%, Germany 28.3%, with Italy the lowest with 19.1%. A more recent analysis, from 2020 is provided in Figure 11 and shows the progress that is currently made towards a target of at least 40% of the population at earlier ages (24-35) who secured tertiary education.

Based on these statistics, if participation in citizen science were spread evenly across the population, about one third of participants would be expected to have tertiary education, and about 1-2% to have a doctoral degree. Yet, the evidence points to a different picture. In Galaxy Zoo, a project in which participants classify galaxies and help astronomers to understand the structure of the universe, 65% of participants had tertiary education and 10% had doctoral level degrees[23]. Curtis[24] also found that in Foldit[25], a project solving puzzles about the structure of molecules, 70% of participants had tertiary education; while in Folding@home[26] a volunteer computing project, 56% had tertiary education. In OpenStreetMap[27], which aims to create a free, editable digital map of the world, 78% of participants hold tertiary education, with 8% holding doctoral level degrees[28]. Finally, Transcribe Bentham[29], a digital humanities project in which

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[23] Raddick et al. 2013; Curtis 2015
[24] Curtis 2015
[25] https://fold.it/
[26] https://folding.stanford.edu Folding@Home
[27] https://www.openstreetmap.org/
[28] Budhathoki & Haythornthwaite 2013
[29] https://www.ucl.ac.uk/transcribe-bentham

volunteers transcribe the writing of 19th-Century English philosopher Jeremy Bentham, 97% of participants have tertiary education and 24% hold doctoral level degrees[30]. In a recent study (2021) about Flemish citizen science[31] 80% of participants were highly educated, with 11% holding a PhD, demonstrating that the trends in other studies continue.

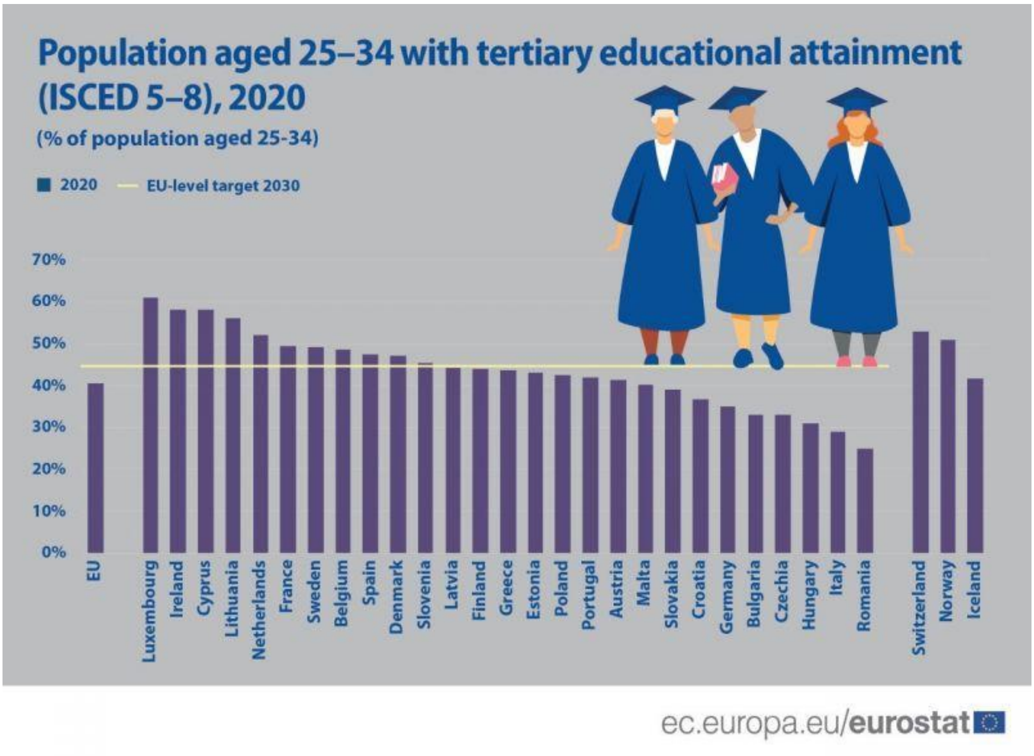

Figure 11: Population aged 25-34 with tertiary educational attainment 2020 (source Eurostat)

These finding show the importance of higher education as creating the basis for participation in citizen science. Of a special interest is the participation of people who hold a PhD, many of them are not employed as professional scientists. It is also clear that as the task complexity increases, the participation of people with higher levels of education increases – for example, Transcribe Bentham requires familiarity with a challenging transcription interface, and knowledge and interest in 19th-Century philosophy.

Across projects, the participation of people with tertiary education is at least twice the level in the general population, and the participation of people with doctoral level education is at least three times higher. Box 4 provides further insights on how to assess this.

[30] Causer & Wallace 2012

[31] Duerinckx et al. 2021

Box 4: Assessing over-participation of the highly educated

The high level of participation by highly educated people can be interpreted in both a positive and negative light.

Positively, the population with higher education has received more societal resources due to their longer period in education and deferring the period in which they are contributing to the economy and society through full-time employment. Those with doctoral level education arguably benefited from this even more due to their longer and more specialised studies. Therefore, the opportunity to contribute to shared knowledge by volunteering to citizen science projects should be seen as a way to harness the knowledge, skills and abilities of those with higher education for a socially beneficial outcome. Put simply, from a science policy perspective **citizen science provides a way to capitalise on the societal investment in increasing levels of education to high levels. It also provides a way to gain access and engage the high number of people with PhDs who are outside the formal R&D system.**

On the other hand, the numbers tell us that citizen science projects, even those that are based on micro-tasks and allow for a lighter level of engagement, are not reaching the wider population, and especially not enough of those without tertiary education. They are therefore not engaging across all sectors of society. Therefore, for the mission to increase societal engagement with science, especially for those with lower levels of education, **citizen science requires guidance and resources to reach out across society.** The XperiLAB example from RBINS (Box 2), or the success of the Open-Air Laboratories project in the UK, as well as the Sparkling Science programme in Austria demonstrate that when a specific effort is dedicated to widening participation, citizen science can be a very effective vehicle for such a goal.

While the level of education can be demonstrated across projects, other demographic aspects show a wider variety. For example, projects also vary in terms of gender. The OpenStreetMap survey showed 97% male[32] participation and an IBM study of World Community Grid showed 90% male participation[33]. However, this gender bias cannot be completely explained by a strong technological component to the project, as other projects show a very different pattern. Transcribe Bentham engages participants in deciphering and transcribing the writings of Jeremy Bentham, on a platform that requires quite some technical skill, and the majority of participants are female[34]. This was also the case for a study of turtle nests in Florida[35]. In the Flemish study mentioned above, of those that identified their gender, 59% were men[36]. Those who observed gender biases

[32] Budhathoki & Haythornthwaite 2013
[33] World Community Grid 2013
[34] Causer & Wallace 2012
[35] Bradford & Israel 2004
[36] Duerinckx et al. 2021

may have other explanations. Cooper and Smith showed[37] that there are observable gender differences in the bird watching community and that they might be linked to wider societal issues. Because citizen science is a societal activity, it is impacted by issues such as ethnicity, income, age groups, and cultural practices.

Finally, when examining citizen science, especially large-scale activities, it is worth paying attention to a phenomenon that has been termed "participation inequality". Participation inequality was first recognised by Hill and his team in 1992[38] while analysing the contribution of different people to the development of digital documents. It manifests in online forums such as mailing lists, discussion forums and games. It is also common in citizen science projects[39]. Across these projects, the proportion of registered people who do not contribute can reach 90% or even more of the total number of participants, especially if we look at those who use the information without contributing to it. Of the remaining participants, 9% or more contribute infrequently or fairly little. Finally, the last 1% contribute most of the information. The phenomenon has therefore been framed as the 90-9-1 rule[40]. However, participation can be very skewed. As Nielsen points out, in Wikipedia, 0.003% of users contribute two-thirds of the content, with a further 0.2% contributing infrequently, making the relationship 99.8-0.2-0.003%.

In summary, the demographic picture of citizen science participants is diverse, and requires attention in design and policy to achieve specific goals. Because of their characteristics, a careful consideration of the appropriate policy goals is needed (as we have seen in section 2.2) with appropriate resourcing and impact assessment to ensure that there is a progress towards them.

3.2 Positioning citizen science within public engagement in science

Citizen science fits comfortably alongside other forms of public engagement in science. During the "Doing it Together Science" project (DITOs[41]), the citizen science escalator (Figure 12) enabled the contextualization of citizen science activities within the wider framing of engagement and communication between science and society[42]. The escalator is positioning activities that require higher levels of commitment higher up. For example, DIY science requires learning skills such as programming, connecting and calibrating sensors, and carrying out data analysis to make sense of the results. In contrast, participation in volunteer computing only requires the downloading and installing of software, and the selection of the projects to participate in, which is not as demanding as DIY science.

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37 Cooper & Smith 2010
38 Hill et al. 1992
39 Haklay 2016.
40 Nielsen 2006
41 https://cordis.europa.eu/project/id/709443/
42 See Skarlatidou and Haklay 2021

Again, as before, it is noteworthy that there is no value judgement about the level of participation. In the same way that we do not expect every citizen to be an R&I start-up entrepreneur, we should not expect all citizens to do DIY science.

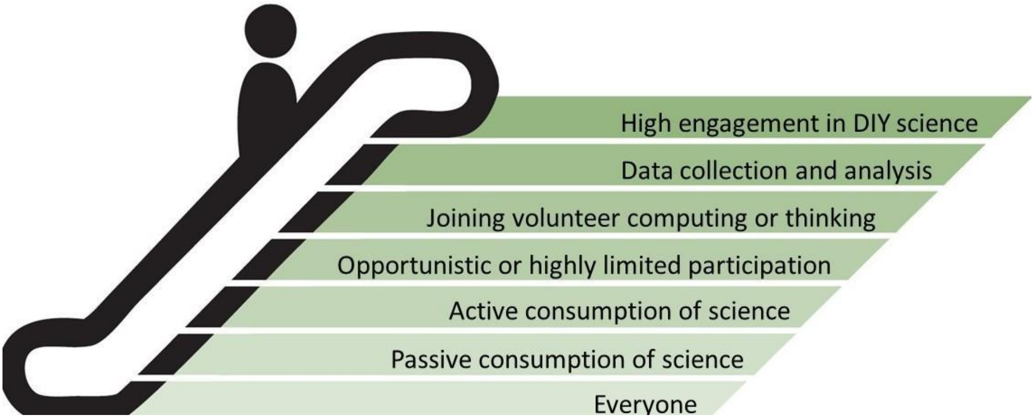

Figure 12: DITOs' citizen science escalator (source Skarlatidou & Haklay 2021)

In addition to understanding the position of citizen science alongside other public engagement with science activities, the escalator also allows for a rough estimation of the current level of participation in citizen science, using the UK as an example, with figures from 2017 as a specific year in which projects were approached to provide statistics. These "back of the envelope" calculations will allow the interpretation of Eurobarometer 516 results (see section 3.3).

At the bottom of the escalator, Level 1 considers the whole population, about 65Mpeople in the UK. Because of the impact of science across society, the vast majority, if not all, will have some exposure to science – even if this is only in the form of medical encounters. The Covid-19 pandemic demonstrated that regardless of your position in society, science influences your life.

Next, the bare minimum of engagement is to passively consume information about science through newspapers, websites, and TV and Radio programmes (Level 2). Gauging the number of people at this level from the BBC programmes focusing on natural history, which in 2017 attracted about 10 to 14M viewers, supporting an estimation of these "passive consumers" at about 25% of the population.

At the next level is active consumption of science – such as visits to London's Science Museum (UK visitors in 2017 – about 1.3M), or the Natural History Museum (UK visitors in 2017 – about 2.1M), if we add to this other local museums, botanic gardens and the like, an estimation of participation at 10% of the population seems justified.

Next, we can look at active engagement in citizen science but to a limited degree. Here we look at the Royal Society for the Protection of Birds (RSPB) annual Big Garden Birdwatch to which participants dedicate one single hour in the year. The project attracted about 500,000 participants in 2017 (and over 1M during the lockdown of 2021)[43], and we can, therefore, estimate participation at this level at 2% of the population at most.

At the fifth level, there are projects that require remote engagement, such as volunteer thinking on the Zooniverse platform, or in volunteer computing on the World Community Grid (WCG). The number of participants in WCG from the UK in 2017 was about 18,000. In Zooniverse about 74,0000 people carried out more than a single task in 2017, thus estimating participation at this level at 0.1% of the population[44].

The sixth level requires the regular data collection, such as the participation in the British Trust of Ornithology Garden Birdwatch got about 6,500 active participants in 2017, while about 5,000 contributed to the biodiversity recording system iRecord and it will be reasonable to estimate that the participation is about 0.01% of the population[45].

The most engaged level include those who are engaged in DIY Science. We can estimate that it represents at most a few hundred people, or 0.001% of the UK population[46].

We can see that as the level of engagement increases, the demand of time and effort from participants increases (for example going through training or spending time at a given location, etc.) and the number of participants drops. Considering the increase in education that we have seen in section 3.1, there is much untapped potential for many more people to be encouraged and to join higher modes of participation. This is an important factor in the scaling up topic within the MLE. In the next section we will look at the European wider results of the special Eurobarometer 516, which looked at science and society relationships.

3.3 Insights from Eurobarometer 516

Eurobarometer provides the gold standard of information about public opinion across the European Union. With a long history of operation, this detailed survey provides the results of hour-long interviews with a carefully selected representative population from across the Member States[47]. Within the wider Eurobarometer surveys, several studies looked at science and societal issues (in 2013, 2010, and 2005). The most recent of these was the Special Eurobarometer 516 study carried out in 2021, which reached out to 37,103 participants in 38 countries - including EU Member States, EU enlargement countries, EFTA states, and the UK[48].

The survey, which took place in the midst of the Covid-19 pandemic, showed a high interest in scientific and technological development issues - with a small

[43] Source RSPB https://community.rspb.org.uk/ourwork/b/rspb-england/posts/big-garden-birdwatch-breaks-records
[44]Source Grant Miller, Zooniverse and Caitlin Larkin, IBM
[45] Source British Trust of Ornithology and Tom August, CEH
[46]Source Philippe Boeing & Ilia Levantis
[47] https://europa.eu/eurobarometer/about/eurobarometer
[48] https://ec.europa.eu/commission/presscorner/detail/en/IP_21_4645

increase in the proportion of those that are very interested in issues such as medical discoveries, environmental issues, and new discoveries since 2010.

While 52% of respondents agree that decisions about science and technology should be carried out by experts (scientists, engineers) and decision makers, 32% think that serious consideration should be paid to public views and preferences. Only 15% think that the public should be involved in decisions about science and technology.

One part of the report is specifically relevant to citizen science, following the escalator model that was described above. Question 14 was dedicated to this issue and asked about direct engagement with science. In Figure 13, the overall results for EU27 are presented, while Figure 13a-d provides the specific results for four countries that participate in the MLE: Portugal, Romania, Germany, and France.

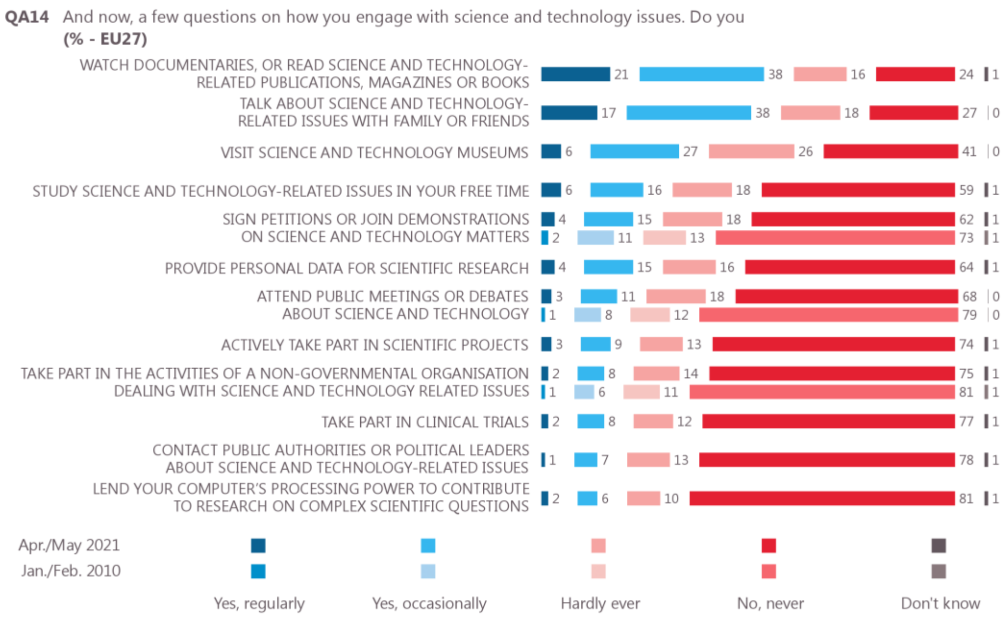

Figure 13 Eurobarometer 516 results for EU27 (source EU Eurobarometer infographic)

We can see that the overall results are matching the overall patterns of engagement for the passive consumption and active consumption of science. Notice that over 55% report regular or occasional engagement through reading or discussion with friends or family. At the second level, a high number report a visit to a science museum or studying (over 30% saying that they visit occasionally). Similarly, 10% report participation in clinical trials. Considering that about 8000 such trials are carried out across Europe, and that on average they do not have more than 2000 participants, this response cannot match the reality. In short, looking at the responses, the safe interpretation of the results is as a declaration of intent and interest. This is highly positive for the potential it holds for engagement in citizen science. With 8% that are willing to lend their computer power to citizen science and 12% that are willing to participate in scientific projects, European society has a large and untapped potential for engagement.

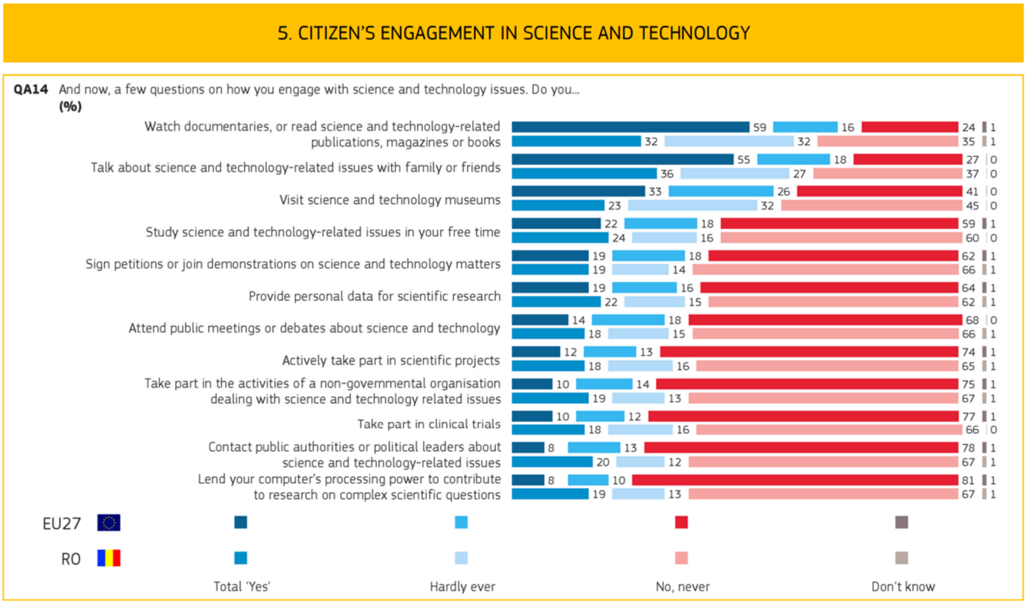

Figure 13a, Eurobarometer 516 question 14 results for Romania (source EU Eurobarometer country factsheet)

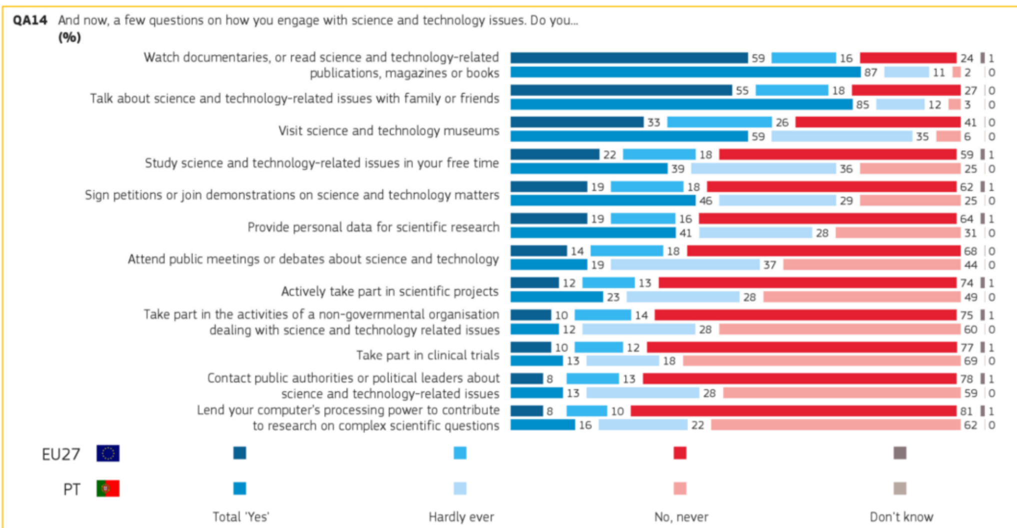

Figure 13b, Eurobarometer 516 question 14 results for Portugal (source EU Eurobarometer country factsheet)

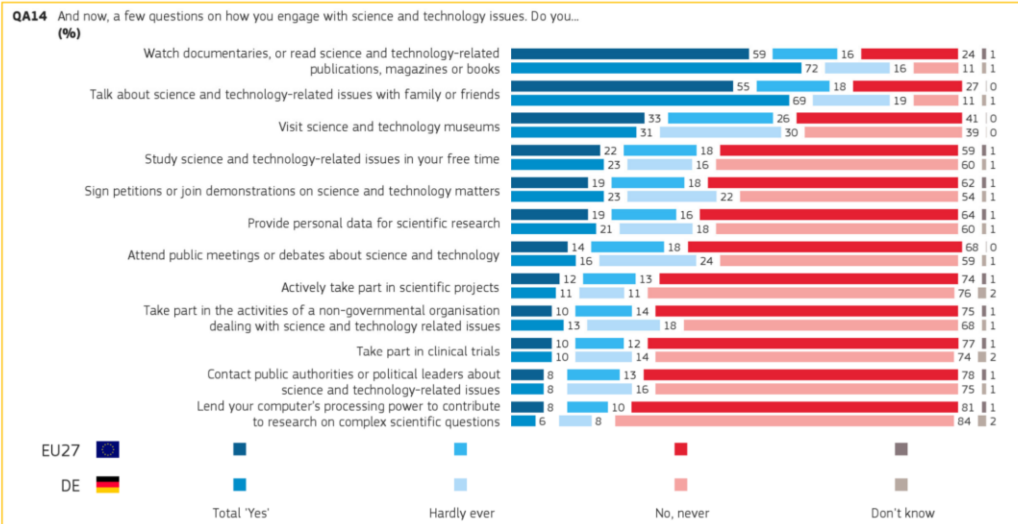

Figure 13c, Eurobarometer 516 question 14 results for Germany (source EU Eurobarometer country factsheet)

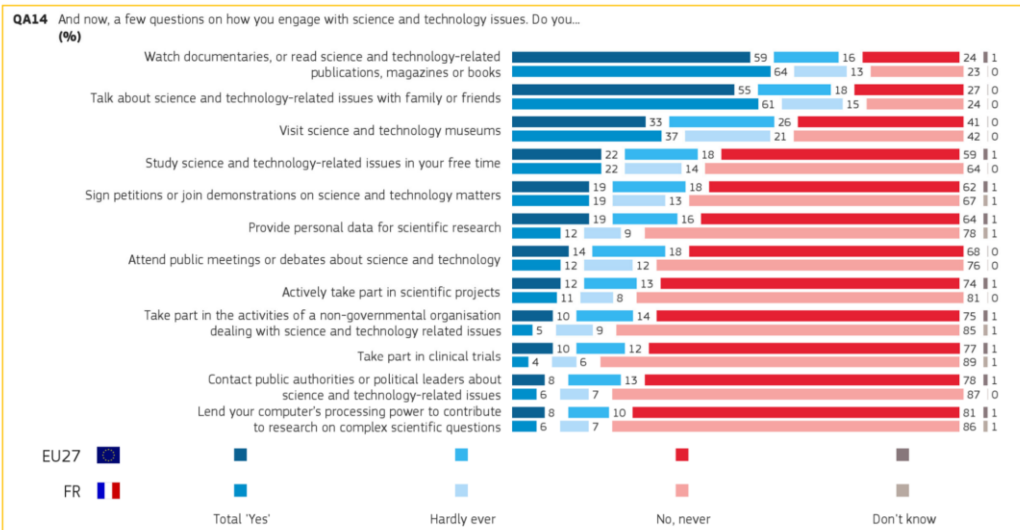

Figure 13d, Eurobarometer 516 question 14 results for France (source EU Eurobarometer country factsheet)

Examining the detailed reports for each country, we can see, as expected, differences in the approach to the value of science in everyday life and the willingness to participate in projects. It is particularly interesting that of these four countries, Romania, where citizen science is less developed, is showing a very high level of willingness to participate in scientific projects. Again, demonstrating the potential.

Another aspect is at the high level of reported passive consumption of science, which is especially high in Portugal (87%) and Germany (72%), indicating that a potential route to engage people in citizen science is through communication with science journalists and ensure that opportunities to move from passive to active participation in science are provided.

4. Defining citizen science and identifying principles and characteristics

4.1 The challenge of defining citizen science

As we have seen throughout the report, the range of activities, forms of engagement, goals, and specific cultural issues means that citizen science is complex and as a result challenging to define concretely. This can be demonstrated by analysing the dictionary definition of citizen science, which was offered by the Oxford English Dictionary in 2014: "**citizen science:** scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions."[49] Even within this definition, the editor chose the word "often", which otherwise would have excluded DIY science which is not under the direction or in collaboration with professional scientists. As we have seen, it is not only scientific work, but also other forms of research work. An analysis of over 30 definitions of citizen science which was carried out in 2020 demonstrated the different foci and emphases within each definition[50].

It is common to see an instrumental aspect within a definition: it must address the objectives of the actors within the activity and the engagement of participants in the knowledge generation processes. Yet, these definitions matter – they enable frameworks and mechanisms and answer the different needs of specific fields of application. For example, when applying for EU funding for a citizen science project, the White Paper on Citizen Science for Europe[51] definition might be helpful "*Citizen science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources*". Indeed, when examining the type of projects that emerge within the different calls for funding (see section 5), we can see that this definition, together with the ECSA principles of citizen science enabled a plurality of approaches, research areas, and modes of participation.

A more up-to-date and addressing engagement in policy definition was developed by the Open Science Policy Platform (OSPP) in 2018: "*Broadly defined, citizen science is 'scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions'. Citizen science is an already very diverse practice, encompassing various forms, depths, and aims of collaboration between academic and citizen researchers and a broad range of scientific disciplines. Civic participation in research can range from short-term data collection to intensive involvement in the research process, from technical contribution to genuine research, and from collaboration to co-creation of knowledge. Yet, there is still a need to define and establish citizen science as a genuine, open research approach*". In short, fitness for purpose is an important aspect when choosing a definition to be used in a

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[49] https://www.oed.com/view/Entry/33513
[50] Haklay et al. 2021
[51] Serrano Sanz et al. 2014

given context. While the need for criteria and definition exist[52], we should recognise the risk of a too narrow definition[53].

For this MLE, we should pay special attention to the EC factsheet on citizen science[54]: "*Citizen science can be described as the voluntary participation of non-professional scientists in research and innovation at different stages of the process and at different levels of engagement, from shaping research agendas and policies, to gathering, processing and analysing data, and assessing the outcomes of research. Active engagement with citizens and society has the potential to improve research and its outcomes and reinforce societal trust in science. It can increase: relevance and effectiveness by ensuring that R&I aligns with needs, expectations and values of society; creativity and quality by enlarging the collective capabilities, the scope of research and the quantity and quality of data; transparency, science literacy and confidence of the public in research*".

It is a deliberately wide definition that can accommodate many forms of participation, which is befitting the needs of the wide goals of Horizon Europe. Yet, this raises a problem: with broad definitions, how will we know what is a high-quality project? How would we know what to fund? A lack of a clear and common definition implies the risk that the concept in itself is eroded and used too often as buzz word thus affecting credibility and appreciation of the approach. We turn to this issue in the next section.

4.2 The pluralistic approach: ECSA 10 principles & ECSA characteristics of citizen science

Awareness of the challenge of definition and the need for a broad approach towards the type of project is well known within the citizen science practitioners community. As a result, significant effort is directed at identifying and communicating what should be recognised as high quality citizen science. In the European context, two major documents were created for this purpose by the European Citizen Science Association (ECSA) community - the 10 Principles of Citizen Science, and the ECSA Characteristics of citizen science.

The 10 principles of citizen science[55] were created by the "Sharing best practice and building capacity for citizen science" working group of ECSA at a very early stage in the organisation's history. The work was led by the London Natural History Museum, and was building on the experiences of projects such as Open Air Laboratories (OPAL) which was carried out in the UK in 2007 and engaged 1M participants. The principles became widely cited and used when they were published in 2015. They provide the basic expectations from a project, if it aims to be a high-quality citizen science project. The principles are outlined in Box 5.

[52] Heigl et al. 2019
[53] Auerbach et al. 2019
[54] European Commission, DG R&I 2020
[55] Robinson et al. 2018

Box 5: ECSA 10 Principles of Citizen Science

Citizen science is a flexible concept which can be adapted and applied within diverse situations and disciplines. The statements below were developed by the 'Sharing best practice and building capacity' working group of the ESCA, led by the Natural History Museum London with input from many members of the Association, to set out some of the key principles which as a community we believe underline good practice in citizen science.

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.**

As we can see, the principles provide both the practical expectations - such as open data, or the way they are recognised in publications - as well as expectations about the ethical conduct of a project.

Despite their popularity, the 10 Principles remain broad in terms of their definition of what is or is not citizen science, although a project that will adhere to all of them is likely to be a citizen science project. They are also targeted more at practitioners than towards funders. The response that ECSA receives from policy makers, funders, and people who are new to citizen science is that the 10 principles are too vague to provide clear guidance that will allow judgement with respect to a proposed activity or an application for funding. Therefore, the ECSA community developed a short guidance document for those who want to make a decision or develop criteria: the ECSA characteristics of citizen science. Such criteria can help them decide which characteristics they would like to select in a project that they will fund, or refer the applicants to a set of characteristics that they would like to see in a project. In contrast to the 10 Principles, the characteristics are not expected to be universal, or to be applied as a complete set, but to assist the adaptation of the interpretation of citizen science to specific cultural and research contexts.

The characteristics were developed through a study that engaged over 330 people[56], and they were launched in April 2020[57]. The document is addressing different issues and is broken into the following sections: core concepts, disciplinary aspects, leadership and participation, financial aspects, and data and knowledge. For example, it is noticing the importance of semantics in fields like biomedical research and social science. In both areas, the difference between a project in which someone is contributing personal information through a mobile phone app and a citizen science project is in the way in which the researchers see the relationships. In cases where the participant is "a subject" of the study and the researchers are trying not to interact with them apart from viewing them as a data point, the project will not be a citizen science project. However, if the researchers are seeing the participants as "co-researchers" and sharing with them the results and exploring with them the research questions, or using other forms of knowledge co-production, the project can be recognised as a citizen science project.

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[56] Haklay et al. 2021

[57] https://zenodo.org/communities/citscicharacteristics/

The characteristics are a reference document that can assist people in the R&I field to recognise projects and activities as citizen science. The characteristics are combined with an annotated interpretation document, that can assist in making sense and understanding the context of the shorter characteristics document. The expectation is that this document will be updated from time to time to address the latest development in the field of citizen science.

5. How citizen science is promoted through EU funding mechanisms

5.1 Citizen science recognition within R&I policy

The European Union is amongst the first international bodies that recognised citizen science. As early as 2008, Prof Jacqueline McGlade, the then head of the European Environment Agency (EEA) noted in a talk in 2008: "Often the best information comes from those who are closest to it, and it is important we harness this local knowledge if we are to tackle climate change adequately."[58] At the same event, the EEA launched a global citizen observatory which started with reporting on the quality of bathing water across Europe. The support from the EEA and DG Environment supported the launch of ECSA during the Green Week of 2013, with active participation by Janez Potočnik, the then Commissioner for the Environment. Further reports on the importance of citizen science within the environmental domain continue to appear[59], as well as efforts to integrate citizen science into the regulations and work programme of the EEA.

Turning to the area of R&I, an early indication of the collaborative effort of the citizen science research community came in the aforementioned White Paper on Citizen Science for Europe[60] which was developed in 2014 as part of the FP7 project Socientize. During the period of Horizon 2020 (2014-2020), policy attention towards citizen science continued to evolve. In addition to research efforts that focus on the environment (most notably, through dedicated investment in Citizen Observatories - see below), the interest in citizen science was also relevant to wider interest in engaging science and society. Significant reports in which citizen science was noted as an important element of the R&I landscape include the Lami Report in 2017[61] in preparation for Horizon Europe. Next, came the analysis of the Open Science Policy Platform[62] in 2020, which explicitly called for actions in the area of citizen science in its ambition 8, recommending that:"

1. Publicly funded Citizen Science projects (as part of FP9 projects) should actively apply the principles of Open Science (including openness and reuse of all research outputs, data and publications).
2. Research-performing organisations (RPOs) are encouraged to promote infrastructures and human capacity to create a supportive and open environment for Citizen Science, which can further strengthen the

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[58] https://www.eea.europa.eu/media/speeches/environmental-information-and-public-participation
[59] Bio Innovation Service 2018
[60] https://eu-citizen.science/resource/8
[61] European Commission, DG R&I 2017
[62] European Commission, DG R&I 2020

outreach of RPOs to society. Research libraries are well placed, amongst others, to contribute actively to the necessary coordination and communication infrastructures as well as relevant training, fostering skills such as community management, co-production of knowledge, Open Science standards and social diversity. Appropriate funding and incentives need to be put in place to support this endeavour.

3. The European Commission must support an online toolkit for Citizen Science in Europe. This tool must promote Citizen Science as a European asset, offering an entry point and mutual learning space, interconnecting with existing activities and infrastructures at the European, national and local level. It should highlight particular achievements and best practices, and promote a clear set of principles, guidelines & quality criteria for Citizen Science.
4. Funding for Citizen Science projects should be flexible, long-term and allow for small or experimental projects in collaboration with key stakeholders to be funded. A small section of FP9 should be set aside for citizens to propose research topics or projects. These should be chosen on the basis that they are high risk, beyond traditional research fields and conform to the rigorous standards expected of other projects. Successful proposers will need to work with compliant institutions."

Within Horizon Europe, the key features for citizen and societal engagement are as follows. Since Open science is the modus operandi of the entire programme, and as within the European framing of Open Science, citizen science is one of the eight pillars, it is promoted as an integral part of all activities. This does not mean that it needs to appear in every single project, but it is expected to have a place across the programme in projects where it will increase the chances of the projects delivering on their objectives. Second, societal engagement is an aspect to be taken into account as part of the excellence criterion under methodology during proposal evaluation and therefore it is something that every proposal will need to consider. So, co-design and co-creation, and engagement of citizens and civil society organisations, are mainstreamed across the programme.

Finally, one of the nine pathways to impact (KIP6) starts with citizens and end-users co-creating knowledge and innovations, with the goal of developing solutions and knowledge that are taken up by society.

In official terms, the Horizon Europe regulations include the following[63]:

"Reg. - Recital (51): ...the Programme should engage and **involve … citizens and civil society organisations in co-designing and co-creating responsible research and innovation (RRI) agendas and contents … that address citizens' and civil society's concerns**, needs and expectations...

Reg. - Programme principle (A7.11): The programme shall promote **co-creation and co-design through engagement of citizens and civil society**

SP - Operational objectives (A2.2): (d) promoting responsible research and innovation, taking into account the precautionary principle; (m) Improving the

[63] European Commission 2018; European Union 2021

relationship and interaction between science and society, including the visibility of science in society and science communication, and promoting the **involvement of citizens and end-users in co-design and co-creation processes**

Open Science, which includes citizen and societal engagement, will be operationalised throughout the programme: **award criteria** for proposal evaluation, **key impact pathways**, and within **topic texts**." (emphasis added)

Beyond the EU, a significant development in relation to citizen science is the recognition of it as a pillar within the UNESCO recommendations on open science[64] from 2021. The recommendation takes a global perspective and considers the needs of all UNESCO Member States, and therefore takes into consideration the abilities, resources, and interests of less and more advanced economies and systems of science and innovation. The preamble recognises the importance of citizen science: "Considering that the collaborative and inclusive characteristics of open science allow new social actors to engage in scientific processes, including through citizen and participatory science, thus contributing to democratisation of knowledge, fighting misinformation and disinformation, addressing existing systemic inequalities and enclosures of wealth, knowledge and power and guiding scientific work towards solving problems of social importance," (p.4)

The recommendation supports the use of citizen science as a methodology, and calls for appropriate support and utilisation of such approaches within the context of open science. Furthermore, they explicitly call on Member States to consider "Enhancing the inclusion of citizen and participatory science as integral parts of open science policies and practices at the national, institutional and funder levels." (p. 22) and invest in "Platforms for exchanges and co-creation of knowledge between scientists and society, including through predictable and sustainable funding for volunteer organisations conducting citizen science and participatory research at the local level." (p. 25). In terms of integration into the scientific process, the recommendation calls for "Developing new participatory methods and validation techniques to incorporate and value inputs from social actors beyond the traditional scientific community, including through citizen science, crowdsource based scientific projects, citizen involvement in community-owned archival institutions, and other forms of participatory science." (p. 30). In short, the recommendations call on Member States to provide the incentives and the appropriate support for running citizen science projects.

Box 6 illustrates the example of Scivil in Flanders, established in 2019 as a knowledge centre for citizen science.

Box 6: Scivil - Citizen Science Flanders

Case provided by Marzia Mazzonetto, Stickydot

Scivil is the Flemish knowledge centre for Citizen Science. Created in 2019, Scivil is an initiative supported by the Government of Flanders, following a

[64] https://en.unesco.org/science-sustainable-future/open-science/recommendation

very successful call to support citizen science projects launched in 2017, which saw a very high number of applications. When launching another call for projects in 2019, the Flemish Department of Economy, Science and Innovation decided to create a centre (Scivil) to provide support to ongoing and future citizen science initiatives.

Flanders is very active in citizen science, having created in 2015 a digital platform for citizen science called "Iedereen Wetenschapper" (Everyone's a Scientist), an initiative by EOS Science and the Flemish Young Academy. In 2016 the Young Academy also published a position statement on citizen science[65]. In recent years, Flanders has seen the development of large citizen science initiatives such as the CurieuzeNeuzen project (see Box 1), as well as other large-scale EU-funded projects such as hackAIR[66], FloodCitiSense[67] and www.hoemeetiklucht.eu, but also a proliferation of smaller scale initiatives, set up by local groups, such as the successful Leuvenair, as well as research projects undertaken by citizens without any input from professional scientists.

Scivil plays a key role within this variegated citizen science scene in Flanders. Acting as a central point of reference uniting, supporting and informing scientists, citizens, governments and companies, it supports project initiators before, during, and after the duration of their project. It also advises scientists, civil society and government agencies about citizen science, it organises several workshops and networking events, as well as activities to bring citizen science closer the general public with events and traveling expositions.

Examples of the type of support to citizen science initiatives provided by Scivil are the recent (Autumn 2021) series of workshops on "Common challenges in citizen science", bringing together citizen science actors to exchange experiences, success stories and challenges, as well as a long list of publications, such as the Data Charter for Citizen Science[68] (only available in Dutch), a guide to the Data Charter for Citizen Science[69] (also available in English) and the guide on Communication in citizen science[70] (in English).

Since April 2021 Scivil has also been running a citizen science project called amai![71], focused on involving citizens in the development of artificial intelligence applications. Amai! does this by bringing citizens and AI experts together around 4 themes (climate & environment, mobility, health, work) to collect ideas. In 5 phases, a smart AI solution is developed for each theme based on socially relevant questions gathered by citizen scientists. The development of the AI solution is always in consultation with citizens, AI experts and experts in the field.

[65] Soen and Huyse 2016
[66] https://cordis.europa.eu/project/id/688363
[67] https://jpi-urbaneurope.eu/project/floodcitisense/
[68] Sterken et al. 2021
[69] Sterken et al. 2021
[70] Veeckman et al. 2019
[71] https://amai.vlaanderen/

5.2 Citizen science in EU and national funding mechanisms

As we saw in the previous section, the bottom-up awareness within the scientific community of citizen science started emerging in the early 2010s. A good example is the Socientize project that was noted above. Another example is the FET-Open EveryAware[72] project that looked at collective sensing, or citizen cyberlab[73] that addressed the use of ICT for creativity and learning. The first call for funding that was dedicated explicitly to citizen science was the 2012 call under the FP7 for citizen observatories ("Developing community-based environmental monitoring and information systems using innovative and novel earth observation applications" ENV.2012.6.5-1). This resulted in five citizen observatories projects: Cobweb[74], WeSenseIt[75], CITI-SENSE[76], Citclops[77], and Omniscientis[78]. It is highly significant that this early investment in citizen science skilled many researchers in the area of citizen science, and it is possible to trace many of the leaders in the field across Europe to their participation in these projects.

The recognition and investment in citizen science continued during the Horizon 2020 programme, with further investment in citizen observatories and in the development of the social and technical infrastructure as part of the Science with and for Society areas.

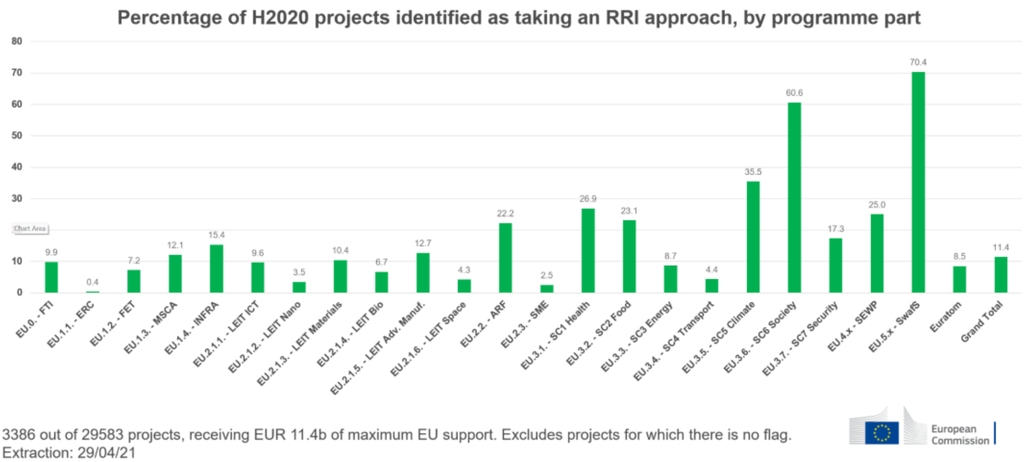

Figure 14: Percentage of H2020 projects identified as taking an RRI approach (source: Linden Farrer, DG R&I)

As the analysis in Figure 13 shows, activities that include a clear element of Responsible Research & Innovation, which usually include a clear public

[72] https://cordis.europa.eu/project/id/265432
[73] https://cordis.europa.eu/project/id/317705
[74] https://cordis.europa.eu/project/id/308513
[75] https://cordis.europa.eu/project/id/308429
[76] https://cordis.europa.eu/project/id/308524
[77] https://cordis.europa.eu/project/id/308469
[78] https://cordis.europa.eu/project/id/308427

engagement in it, are spread across the programme. Of particular importance to note is that within the area of "excellent research" (area 1), there are a significant number of activities. It is also noticeable that the frontier research that the European Research Council (ERC) supports represents the smallest percentage. This demonstrates the journey that practices such as citizen science have to go through to be recognised and adopted.

Although Horizon Europe has just started, there is plenty of scope to integrate citizen science within the different pillars, clusters and missions. The cascading grants mechanism, which was introduced in Horizon 2020 can be an important mechanism to the widening use of citizen science. This is because it is enabling smaller organisations and actors to gain access to funding and support. Some calls that include topics that allow for cascading grants are already included in Horizon Europe.

We also need to recognise that funding for citizen science is also available in other R&I related funding streams such as Life+ or Erasmus+, and there are also national/regional funding programmes (see Box 6 and Box 7 for examples from Belgium).

Box 7: The Brussels Co-create Support Centre

Case provided by Louise Stokart, Co-create Support Centre

The Co-create Support Centre, run by the Confluences association, is located in Brussels and has developed an expertise in supporting the production of knowledge in co-creation. Since 2015, the team has accompanied some 20 participatory action research (PAR) projects in the Brussels Region, financed by Innoviris, the R&I funding body for the Brussels region, via the Co-Create Action. This programme supports projects that propose societal innovations in the context of potential disruptions in the interdependent services on which our urban society is based (in particular the limitation of mineral and energy resources). Understanding the crisis and seizing the opportunity to move towards a sustainable trajectory is, in other words, one of the objectives.

In concrete terms, the projects that are funded carry out co-creative research, i.e., research work rooted in the neighbourhoods, in the streets (in a "living laboratory"), in which all the actors concerned by the issue take part with their view to the collective construction of knowledge[79]. There are multiple challenges in having citizens as researchers, placing academic researchers in situations of co-creation, and non-governmental organisations in work which, although anchored in the field, no longer aims to carry out an action for its own sake but a research project intended for others.

The Co-create Support Centre therefore offers training courses and working groups that allow to collectively examine in greater depth the issues encountered by those who carry out such projects (for example, how to articulate the position of scientists with that of local actors, which

[79] See www.cocreate.brussels

participatory action research tools to use in different circumstances, etc.). It also closely follows the evolution of the projects in order to listen carefully and suggest ways to overcome the obstacles.

Figure 14 Co-creation training day in Brussels (source: Co-Create Brussels)

The Co-create Support Centre has developed and offers a framework that combines methodological approaches for implying different types of actors and bringing together their knowledge, an individual and collective support to the project team and its members, and cross-learning and networking with similar types of projects on a vast range of topics covering urban resilience (urban agriculture, social inequalities, energy,…). The Centre also advises and guides projects and project participants to situate themselves in a broader, systemic approach towards urban resilience. The Centre also conducts other types of participatory projects (for example the development of citizen juries to evaluate and select projects that merit public funding).

For more information: www.confluences.eu

6. Next steps

6.1 The aims and modus operandi of the MLE-CS

The **purpose** of the MLE is to facilitate an exchange of information, experience and lessons learned, as well as to identify good practices, policies and programmes to support and scale up citizen science at the local, regional and national levels. An additional objective is to identify citizen science campaigns that have high potential to be implemented in a collaborative way across the ERA.

The MLE is structured in five rounds of **meetings** on specific **topics** that have been pre-identified by the participating countries, and were presented and agreed upon by all participants during the first meeting. The first meeting on Topic 1 (Introduction and overview of citizen science) has now been held, and the remaining meetings will address:

- Topic 2: Ensuring good practices and impacts
- Topic 3: Maximising the relevance and excellence of citizen science
- Topic 4: Enabling environments and sustaining citizen science
- Topic 5: Scaling up citizen science

Prior to each meeting the participants are provided with pre-reading and pre-listening inputs, including a ***Challenge Paper*** on the specific policy challenge that is the focus of that meeting.

The **meetings** were originally intended to take place in different countries so as to enable the possibility of having local site visits to see the practical implementation of different citizen science projects in the Member States. As a result of the current Covid-19 situation and in order not to delay the project, it was decided to hold the first and second meetings online via Microsoft Teams. In order to ensure that the online meetings are engaging and facilitate knowledge exchange and discussions, the expert panel has developed a number of interactive activities. The first two meetings in the series have also been split over two half-days to ensure effective engagement.

It is currently planned for Topics 3, 4 and 5 that the **meetings** will take place in person in different Member States and follow a two-day format consisting of discussions, presentations, break out groups and site visits. The countries for the visits are Austria, Germany, Hungary and Slovenia.

The **outputs** of each of these five meetings will include summary *minutes* of the main points discussed during the meetings and *thematic reports* on the respective topics, in addition to the challenge papers. The thematic reports will include good practices, lessons learned and success factors identified in the meetings.

A **final meeting** will be organised in DG R&I offices in Brussels to present and gather participant feedback on the draft *Final Report* and agree on the findings, experiences, conclusions and recommended ways to tackle the challenges that were the focus of the MLE. The MLE Final Report will include good practices, lessons learned and success factors based on robust evidence about the impacts of those measures.

A **dissemination event** will be organised in Brussels which will serve as an opportunity to present the results of the MLE to a wider audience, and highlight possible follow-up initiatives from the MLE.

The **roadmap** timeline for the MLE is:

- Topic 2 Meeting: 7 and 14 March (09.30-12.30 CET for both dates)
- Topic 4 Meeting: 7 and 8 June (Part I if in person in Austria); 12 and 13 September (Part II if in person in Hungary); 6 and 13 September (09.30-12.30 CET for both dates if online)
- Topic 3 Meeting: 10 and 11 October (if in person in Slovenia) (09.30-12.30 CET for both dates if online)
- Topic 5 Meeting: 7 and 8 November (if in person in Germany) (09.30-12.30 CET for both dates if online)
- Final Meeting: 13 December
- Dissemination event: early 2023 (exact date TBD).

6.2 Top questions about Citizen Science for the MLE

Prior to the first kick-off meeting we asked participants to fill in a short survey that included the invitation to share the top three questions that they would like to have addressed during the MLE. The resulting questions have been clustered together by subject matter and given a weighting based on the frequency with which they were raised, as shown in the table below.

The first subset of questions regarding a definition of Citizen Science was used as an input for this report, and the remaining questions will serve as inputs to the upcoming topics during the remainder of the MLE.

<table>
<tr><td>Definitions of citizen science</td></tr>
<tr><td>
How broadly can we define citizen science (where is the line between citizen science and science promotion, if there is one)? 10
How can we agree on a common definition of citizen science, it seems that people understand different things when they hear the word? 8
Mutual agreement of a definition of citizen science? 6
</td></tr>
<tr><td>Citizen science and policy</td></tr>
<tr><td>
Examples of citizen science for policy (contributions to governments)? 12
How to take impact into account? 10
What should we expect from citizen science projects/initiatives and how to properly integrate them into the overall science policy priorities? 10
How can results from citizen science projects be implemented in policy decisions more easily? 8
Citizen science also from the policy/programme perspective (which are the most relevant and efficient policies/actions/strategies for supporting the development of citizen science at national level taking into account the transition process towards open science is at the beginning and the fact that citizen science is at the early stage of development). 5
</td></tr>
</table>

Research environment, interaction, and infrastructure
• How could we raise the interest for the involvement of citizens in science/research projects? What are the basic activities that should be taken into consideration within capacity building for citizen science? 7 • What are the needed infrastructures (IT-tools, applications, recruitment and best practices) for relevant, ethically sound and successful citizen science? 7 • How to ensure quality of data and quality assurance of research outcome? 7 • How to build a community of citizen science projects - barriers to getting started and how to establish partnerships? 6 • How can we best support the exchanges (in time and financially) between citizens and scientists? 6 • How effective are top-down initiatives (i.e., supported and top-down led) of citizen science and what should be avoided in this respect? 4 • How could we develop and sustain citizen science research in the social sciences and humanities? 2 • How to train the participants without biassing the results? 2
Incentives and engagement
• How can we best valorise/reward the citizen science activities of researchers? 10 • How do we ensure that citizen science is given enough merit? 9 • How can citizen science projects engage more audiences? How to build a convincing campaign? 8 • How can interdisciplinarity contribute to visibility and legitimisation of citizen science? 7 • How can citizens be better informed of citizen science activities so they can take part at local, national or international levels? 7 • How can we best support the exchanges (in time and financially) between citizens and scientists? 6 • How to engage participants? 3 • How can hard-to-reach groups be involved in citizen science projects? 3

Funding
• How to take impact into account? 10 • Can we share examples of successful citizen science funding schemes/programmes/calls for proposals existing at European level – developed by other European research funding organisations (e.g., objective, what activities were funded, types of projects funded)? 5 • Funding is a big issue. Sometimes it is very challenging to convince research funding organisations to support a Citizen Science project. How could Citizen Science be more efficiently promoted for funders? 4 • What are typical challenges in European citizen science projects? Are they similar to those in national projects? And what are the pitfalls in the scaling-up of transnational European citizen science campaigns? 4 • How can citizen science projects be (financially) supported over a longer period (more than 3 years), since many citizen science initiatives are pursuing long term goals? 3
Barriers and concerns
• How can we ensure that the data from citizen science is trusted? 8 • How can the often-heard reservations from scientists regarding citizen science (too inaccurate, too expensive etc.) be best countered? Could digitalisation be a useful instrument as digital tools facilitate access and ensure high data quality? 4 • There are so many misunderstandings around Citizen Science. I heard some scholars think that people cannot do research, cannot make science. What can we do to promote Citizen Science among these scientists? 3
Other Questions
• How can the increasing appreciation of science over the course of the Covid-19 pandemic be used to engage more citizens in citizen science projects? 1 • How to steer the process without interfering? 1

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This report provides background information on the Mutual Learning Exercise on Citizen Science. It is written with a science policy audience in mind and provides an introduction and details of the modus operandi for the MLE. The report first provides a brief overview of the activities that are part of the field of citizen science. It then covers the available information about participation, and the place of citizen science within the wider context of public engagement with science, including an analysis of Special Eurobarometer 516. The report also looks at definitions, typologies, and best practice guidelines. Finally, it looks at the place of citizen science within European R&I funding programmes.

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