REFLECTING ON DIFFERENT NATURES OF CITIZEN SCIENCE ENDEAVOURS

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1. Introduction

The rapid pace of innovation driven by the so-called Moore's Law, Metcalfe's Law and the growing efficiency and efficacy of data storing infrastructures, exponentially amplify the potential of data driven innovations, including citizen-generated data. These trends underpin the capacity (per price) of processing, network, and storage capabilities leading to widespread adoption of digital technologies across domains. If coupled with more and more established open innovation and open science principles and paradigms, as well as with new possibilities and policy-led priorities for engaging lay people in scientific enquiries, give rise to the discipline of Citizen Science[1].

1.1 Citizen Science

The involvement of lay individuals in scientific research can take many shapes and forms, and generally identifies the active engagement of citizens in one or more phases of a scientific inquiry. These phases typically include actively participating in exploring and formulating issues to be investigated, co-design the protocols and the governance of the project and the data collected, the actual data collection and analysis phases, and, ultimately, the processes where results are reflected upon, and the legacy of the research is established. These endeavours generally come together under the umbrella of citizen science. Citizen science, as a concept, has diverse definitions, terms, and interpretations, where no single term or definition is suitable for all contexts[2]. Different approaches have been advocated and instantiated to date across domains. These typically vary in terms of several distinct factors. Primarily, academics and practitioners tend to distinguish citizen science projects based on the actual role assumed by citizens in these processes. Those cases whereby citizens are actively involved across phases are known as Extreme Citizen Science[3]. More generally, citizen science is being established to create a bridge between two worlds (i.e. the academic/scientific and the societal ones) which so far have been somewhat distant. In other words, citizen science is a more and more acknowledged way to democratize science itself.

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[1] Balestrini, Mara; Rogers, Yvonne; Hassan, Carolyn; Creus, Javi; King, Martha; Marshall, Paul. "A City in Common: a Framework to Orchestrate Large-Scale Citizen Engagement around Urban Issues". A: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 2017, pp. 2282-2294).

[2] Eitzel, M.V. et al. "Citizen science terminology matters: exploring key terms". *Citizen Sci*, Vol. 2, Núm. 1, (2017). https://doi.org/10.5334/cstp.96 [Consulta: 01/05/2024].

[3] Chiaravalloti, Rafael Morais; Skarlatidou, Artemis; Hoyte, Simon; Badia, Marcos Moreu; Haklay, Muki; Lewis, Jerome. "Extreme citizen science: Lessons learned from initiatives around the globe". *Conservation Science and Practice*, Vol. 4, Núm. 2, (2022).

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Citizen science over the last decade has proven effective in several different directions and domains. Mainly driven by the European Commission Science with and for Society H2020 Program[4], citizen science is more and more becoming an acknowledged approach to partially address some of the most pressing challenges we are currently facing in our society[5][6] . At the same time, while the potential of Citizen Science and, more generally, Citizen Generated Data (CGD) is well known and well acknowledged across different fronts, its actual impact is still scattered and, sometimes, anecdotal [7] [8]. The extant literature shows a wide range of issues that are currently inhibiting these potentials. These typically include:

(1) Lack of upscaling and sustainability of Citizen Science interventions: Citizen Science projects are typically publicly funded in the form of experimentations of novel ways for engaging lay people in scientific research. The European Commission played a crucial role in fostering these endeavours, e.g. through the Science with and for Society (SwafS) program[9]. Evidence shows the difficulty of these projects to ensure continuity beyond the funding period, sometimes because of the lack of viable sustainable (business) models[10] [11].

(2) Quality of the output: often Citizen Science projects focus on generating data about a given phenomenon. This, depending on the domain, is meant to be used for different purposes, e.g. policy

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[4] Comisión Europea, Dirección General de Investigación e Innovación, Iagher, R., Monachello, R., Warin, C., et al., *Science with and for society in Horizon 2020 : achievements and recommendations for Horizon Europe*, Delaney, N.(editor), Tornasi, Z.(editor), Publications Office, 2020, https://data.europa.eu/doi/10.2777/32018

[5] Fraisl, Dilek; Campbell, Jillian; See, Linda; Wehn, Uta; Wardlaw, Jessica; Gold, Margaret; Moorthy, Inian; Arias, Rosa; Piera, Jaume; Oliver, Jessica L.; Masó, Joan. "Mapping citizen science contributions to the UN sustainable development goals". *Sustainability Science*, Núm. 15, (2020), pp.1735-1751.

[6] Fritz, Steffen; See, Linda; Carlson, Tyler; Haklay, Muki; Oliver, Jessie; Fraisl, Dilek; Mondardini, Rosy; Brocklehurst, Martin; Shanley, Lea; Schade, Sven; Wehn, Uta. "Citizen science and the United Nations sustainable development goals". *Nature Sustainability*, Vol. 2, Núm, 10, (2019), pp.922-930.

[7] Maccani, Giovanni; Goossensen, Margriet; Righi, Valeria; Creus, Javier; Balestrini, Mara. *Scaling up Citizen Science*. Luxembourg: Publications Office of the European Union, 2020, ISBN 978-92-76-25157-6, doi:10.2760/00926, JRC122219.

[8] Bonney, Rick. "Expanding the impact of citizen science". *BioScience*, Vol. 71, Núm. 5 (2021), pp.448-451.

[9] European Commission, Directorate-General for Research and Innovation, Iagher, R., Monachello, R., Warin, C. et al., *Science with and for society in Horizon 2020 – Achievements and recommendations for Horizon Europe*, Delaney, N.(editor), Tornasi, Z.(editor), Publications Office, 2020, https://data.europa.eu/doi/10.2777/32018

[10] Maccani, Giovanni; Goossensen, Margriet; Righi, Valeria; Creus, Javier; Balestrini, Mara. *Scaling up Citizen Science*. Luxembourg: Publications Office of the European Union, 2020, ISBN 978-92-76-25157-6, doi:10.2760/00926, JRC122219.

[11] Fritz, Steffen; See, Linda; Grey, François. "The grand challenges facing environmental citizen science". *Frontiers in Environmental Science*, Vol. 10 (2022), p.1019628.

making or further research. The issue resides in the sometimes reluctance of adopters in considering this data as of sufficient quality, accuracy, and reliability[12] [13] [14].

Still, we argue that these current statements are based on aggregated thinking and analysis, rather than considering the specificities and peculiarities of the different elements and approaches adopted. This paper proposes a reflection on these differences and highlights how priorities, methodologies and approaches should change based on certain characteristics of these Citizen Science projects, such as the field in which these are situated, the data they generate, the task granularity asked to the participating citizens, and the types of results delivered to mention a few[15] [16].

2. Citizen Science Domains and Contributions

First and foremost, Citizen Science projects differ by domain or field of study. The literature and practitioners-based publicly available material showcases the application of Citizen Science in a wide variety of issues and fields. Clearly, environmental-related issues and those addressing climate change more generally, are among the most commonly encountered. Within these, the most popular appear to be those addressing biodiversity-related research, a field where the contribution of Citizen Science is well acknowledged (Chandler et al., 2017; Johnston et al., 2023).

Several examples can also be found with respect to air quality monitoring, e.g. Sensor.Community[17], noise pollution[18], or measuring a combination of these and other elements like humidity and lighting such as in the case of projects based on the IoT sensors Smart Citizen Kit[19].

[12] Hunter, Jane; Alabri, Abdulmonem; van Ingen, Catharine. "Assessing the quality and trustworthiness of citizen science data". *Concurrency and Computation: Practice and Experience*, Vol. 25, Núm. 4 (2013), pp.454-466.
[13] Kosmala, Margaret; Wiggins, Andrea; Swanson, Alexandra; Simmons, Brooke. "Assessing data quality in citizen science". *Frontiers in Ecology and the Environment*, Vol. 14, Núm. 10 (2016), pp.551-560.
[14] Vaddepalli, Krishna; Palacin, Victoria; Porras, Jari; Happonen, Ari. "Taxonomy of data quality metrics in digital citizen science". A: *Intelligent Sustainable Systems: Selected Papers of WorldS4 2022*. Singapore: Springer Nature Singapore, 2023. pp. 391-410.

[15] Chandler, Mark; See, Linda; Copas, Kyle; Bonde, Aatrid; López, Bernat Claramunt; Danielsen, Finn; Legind, Jan Kristoffer; Masinde, Siro; Miller-Rushing, Abraham J.; Newman, Greg; Rosemartin, Alysa. "Contribution of citizen science towards international biodiversity monitoring". *Biological conservation*, Vol. 213 (2017), pp.280-294.
[16] Johnston, Alison; Matechou, Eleni; Dennis, Emily B. "Outstanding challenges and future directions for biodiversity monitoring using citizen science data". *Methods in Ecology and Evolution*, Vol. 14, Núm. 1 (2023), pp.103-116.
[17] Map Sensor.Community https://maps.sensor.community/#3/40.00/15.00
[18] Pharr, Luren D.; Cooper, Caren B.; Evans, Brian; Moorman, Christopher E.; Voss, Margaret A.; Vukomanovic, Jelena; Marra, Peter P. "Using citizen science data to investigate annual survival rates of resident birds in relation to noise and light pollution". *Urban Ecosystems*, Vol. 26, Núm. 6 (2023), pp.1629-1637.
[19] Smart Citizen Kit https://smartcitizen.me/

Within this category other instances of projects can be encountered addressing water quality issues, the most popular being the global Freshwaterwatch[20], waste management[21], Odour pollution, e.g. D-Noses[22], microplastic monitoring and the globally spread Plastic Pirates initiative[23], or soil quality like in the case of the Grow Observatory[24].

One common denominator, or trend, among projects within the environmental domain is that contributions typically involve adding monitoring and observational capabilities to the phenomena of interest. In other words, Citizen Science in these fields usually provides data to enable others to conduct further research or actions based on this novel source of information.

The subsequent reflection leads to argue that the most typical contribution of Citizen Science to environmental studies is providing a more granular understanding of the issue being tackled, typically in a mapping format, i.e. geospatial data. For example, this could refer to more granular data about air quality (typically officially measured at the district level), or of the presence of certain animal species.

Other fields of study where Citizen Science contributions can be encountered in the form of monitoring and mapping include (but are not limited to): healthcare[25], mobility[26] for mobility counting (e.g. WeCount[27]), food[28] like in the case of FoodMapping[29], circular economy[30], energy[31], and even in relation to connectivity and Radio Frequency Electromagnetic Fields (RF-EMFs) like in

[20] FreshWater Watch https://www.freshwaterwatch.org/

[21] Requena-Sanchez, Norvin; Carbonel-Ramos, Dalia; Moonsammy, S.; Klaus, Robert; Punil, Leoncio Sicha; Ng, K.T.W. "Virtual methodology for household waste characterization during the pandemic in an urban district of Peru: citizen science for waste management". *Environmental Management*, Vol. 69, Núm. 6 (2022), pp.1078-1090.

[22] D-Noses https://dnoses.eu/

[23] Plastic Pirates – Go Europe! https://www.plastic-pirates.eu/es

[24] The GROW Observatory https://growobservatory.org/

[25] Ciasullo, Maria Vincenza; Carli, Mariarosaria; Lim, Weng Marc; Palumbo, Rocco. "An open innovation approach to co-produce scientific knowledge: an examination of citizen science in the healthcare ecosystem". *European Journal of Innovation Management*, Vol. 25, Núm. 6 (2022), pp.365-392.

[26] Storme, Tom; Benoit, Sien; Van de Weghe, Nico; Mertens, Lieze; Van Dyck, Delfien; Brondeel, Ruben; Witlox, Frank; Zwartjes, Luc; Cardon, Greet. "Citizen science and the potential for mobility policy–introducing the bike barometer". *Case Studies on Transport Policy*, Vol. 10, Núm. 3 (2022), pp.1539-1549.

[27] We Count https://www.we-count.net/

[28] Pateman, Rachel M.; De Bruin, Annemarieke; Piirsalu, Evelyn; Reynolds, Christian; Stokeld, Emilie; West, Sarah E. "Citizen science for quantifying and reducing food loss and food waste". *Frontiers in Sustainable Food Systems*, Vol. 4 (2020), p.589089.

[29] PEMB. *FoodMapping, una exploración ciudadana sobre el entorno alimentario que se enmarca en el proyecto Big D(ie)ta* https://pemb.cat/es/noticias/foodmapping_una_exploracion_ciudadana_sobre_el_entorno_alimentario_que_se_enmarca_en_el_proyecto_big_dieta/209/

[30] Milios, Leonidas. "Engaging the citizen in the circular economy: Transcending the passive consumer role". *Frontiers in Sustainability*, Vol. 3 (2022), p.980047.

[31] Wuebben, Daniel; Romero-Luis, Juan; Gertrudix, Manuel. "Citizen science and citizen energy communities: A systematic review and potential alliances for SDGs". *Sustainability*, Vol. 12, Núm. 23 (2020), p.10096.

the case of the currently active Etain project[32] where exposure to these forms of radiations is being mapped.

Other projects appear to be more sociological in nature, whereby the impacts being addressed revolve around creating and nurturing communities for more structured and effective engagement in democratic processes and decision making, in the form of education, or to foster awareness to ultimately change societal behaviors towards more sustainable or healthier habits.

However, while these examples show the general trend in terms of contributions (i.e. providing a more granular understanding of an issue or phenomenon or adding qualitative contexts to these issues), these may vary further in relation to at least three interrelated elements: (1) the role of citizens in the initiative of project; (2) the tasks associated to the contribution provided; and (3) the outputs and outcomes sought and, sometimes, achieved. These three elements are tackled separately in the following sections below.

3. Role of Citizens

When reflecting on different citizen science projects, two basic questions emerge with respect to citizen participation: (1) what level of participation is in place? and (2) what does the citizen contribution and task consist of? These are tackled in this section.

3.1 Participation and Engagement level

As described above, citizen science is underpinned by citizens and lay people to assume an active role in one or more phases of a scientific inquiry. The extent of active engagement, i.e. the phases in which they are actually involved, identifies different endeavours. We discuss here three collectively exhaustive categories. In doing so, we relate active engagement to the actual level of accountability of citizens, with each layer identifying a growing level of participation in the project, action or initiative at stake.

Citizen science projects can be classified into three levels of citizen participation: participate, co-design, govern

1. Participate / Contribute: this first layer, which appears to be the most common among existing citizen science endeavours, includes various levels of active involvement which, however, are typically limited to data contributions to tasks or research processes that are fixed and pre-defined by those organizations leading or funding the project itself. In general, citizen science projects can be led by: (1) the communities of citizens themselves; (2) university or research institutes and centres; (3) private companies or entities; (4) public agencies; and (5) other civic actors or NGOs. Clearly, projects in this category can belong to any of these forms, apart from (1). In other words, these projects typically leverage data collected by citizens in a pre-defined methodological and procedural framework.

[32] ETAIN project https://www.etainproject.eu/

It is noted that these participations and contributions may be underpinned by completely different levels of granularity of the tasks. As an example of low task granularity, the project ETAIN mentioned above, leverages GPS and other mobile data provided by citizens who simply agree once to give access to this information. The scope of this specific project is to crowdsource from citizens data about mobile phones - related exposure to Radio Frequency Electromagnetic Fields. On the contrary, some projects within biodiversity demand higher efforts for contributing, such as taking pictures, classifying them, adding text-based characteristics when uploading them etc. The most popular example of these refers to the iNaturalist[33] citizen science platform (see next section).

2. Co-Design: at this second level, in addition to participating and contributing, citizens are typically responsible for the co-design of certain aspects of the project, or to co-create some of its fundamental tools or outputs. Like in the previous case, these projects are however governed by other bodies or consortia than the community of citizens themselves. In this cluster, citizens typically actively participate in the design and selection of research questions and the co-design of technologies and/or other aspects of the defined intervention. Other projects included in this cluster include the citizens' responsibility of taking some critical decisions during the planning and implementation phases. For example, in Mapa Sonoro Barcelona[34], citizens assumed a key role in establishing the locations from where measurements are taken from. Conceptually similar, in Cities-Health[35], a multi-country project of citizen science in the discipline of environmental epidemiology, in Barcelona the community of citizens participating in it democratically decided the research question among a wide range of diverse options proposed as feasible by scientists (the actual research question defined revolved around the impact of exposure to air pollution on people's mental health)[36]. All in all, the vast majority of projects and initiatives labelled as "citizen science" in the academic and practitioner literature belong to this or the previous category.

3. Govern: finally, at the highest level of accountability for the citizen scientists, projects or initiatives may be owned and fully governed by citizens themselves. In other words, these are cases of those actions led and financed by the communities themselves. Examples of these are difficult to find in the extant literature, since their purpose is typically not merely scientific and related to dissemination and diffusion. Rather, the vast majority of these aim at improving or solving very localized problems that usually affect the community of citizen scientists themselves. In other words, because of several reasons, the main ones being capacities and funding, these endeavours are typically locally organized (e.g. a community in street or neighbourhood) to advance the individuals' local agenda. A main pattern in these actions and interventions is as follows: given a locally experienced issue (e.g. traffic, air or noise pollution), communities typically form and work together to produce scientifically reasonable evidence about the issue itself, e.g. data. Based on this increased understanding the communities either use it for advocacy purposes (e.g. ask government agencies to

[33] iNaturalist https://www.inaturalist.org/

[34] Ajuntament de Barcelona. *Mapa Sonoro de Barcelona* https://www.barcelona.cat/barcelonaciencia/es/ciencia-la-ciutat/la-ciencia-i-la-ciutadania/ciencia-ciutadana/mapa-sonoro-de-barcelona

[35] Cities Health https://www.citieshealth.eu/

[36] Froeling, Frederique; Gignac, Florence; Toran, Raul; Ortiz, Rodney; Ficorilli, Antonella; De Marchi, Bruna; Biggeri, Annibale; Kocman, David; Ftičar, Jure; Tratnik, Janja Snoj; Andrusaityte, Sandra. "Implementing co-created citizen science in five environmental epidemiological studies in the CitieS-Health project". *Environmental Research*, Vol. 240 (2024), p.117469.

address the issue they are providing evidence for) or, in some cases, try to work with these agencies themselves to propose and implement solutions. Recently, in a deeper reflection[37] on these communities-led initiatives is provided, with a specific focus on their relationship with public governmental agencies.

3.2 Citizens as knowledge makers: what type of knowledge and how?

Above we reflected on different levels of participation of citizens in citizen science. Another important distinction among citizen science projects refers to the actual data and knowledge that is generated and used in these actions. This is also related to the actual task granularity that is foreseen for participating citizens in one of the phases where citizen science is more commonly leveraged, i.e. to collect and/or generate data as sources of evidence to create knowledge about a phenomenon of interest.

One way to provide a distinction is to separate those situations where data is produced by the actual citizens from those where citizens provide access to their own data that is produced by another means, typically a sensor-enabled technology.

3.2.1 Data production

The former category, i.e. data directly produced by citizens can, in turn, be broken down into at least three further types. First, citizen science data can be produced in the form of documented observations. In this case, citizen scientists are tasked with producing and submitting multiformat data about phenomena, such as photos, audiovisual material, or text. These scenarios are prominent in one of the most successful fields of citizen science, i.e. biodiversity. Here citizen scientists typically submit pictures or other data as evidence of plants or animal species to achieve a granular understanding of biodiversity performances across domains. As mentioned above, the iNaturalist platform is arguably becoming the global standard in this way. Other examples may be found when citizens produce evidence for, e.g. diverse degrees of accessibility in urban environments (e.g. the Wheelmap initiative[38]), or those that leverage the well-established photovoice methodology[39] (Hergenrather, 2009). A second type of data produced comes from survey data, typically in the form of questionnaires. These may exist as the only form of data produced or as complementary to other data being collected. As an example of the latter, survey data may be generated to complement quantitative measures from sensors with qualitative data from citizens, typically adding context and aiding the interpretation of the hard data generated (e.g. about noise, air pollution, traffic etc.). The third type of production considered, refers to the one of physical samples. These may include for instance tap water samples for investigating water quality in a given environment (e.g. see the Aigua

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[37] Errandonea, Lucía. *Exploring the impact of digital transformation on public governance - A community perspective*. Luxembourg: Publications Office of the European Union, 2023. ISBN 978-92-68-02567-3. doi:10.2760/679503.

[38] Wheelmap – Find wheelchair accessible places. https://wheelmap.org/search

[39] Hergenrather, Kenneth C.; Rhodes, Scott D.; Cowan, Chris A.; Bardhoshi, Gerta; Pula, Sara. "Photovoice as community-based participatory research: A qualitative review". *American journal of health behavior*, Vol. 33, Núm. 6 (2009), pp.686-698.

BCN project[40]), samples of microplastic (e.g. in the Paddle Surfing for Science project[41]), or even biological samples like in the case of *Saca la Lengua*[42] whereby citizens donated samples of their saliva for medical research purposes.

3.2.2. Data Access

The second type refers to data typically produced by sensors owned or hosted by the citizen scientists and shared for a given purpose. The task for the citizen scientists is typically associated with installing and maintaining data generation devices (e.g. sensors) and giving/enabling/allowing access to the data it generates. It is important here to make a distinction between ambient sensors and individual ones. The former are sensing technologies that produce data about an environment and its characteristics and/or conditions. Examples of these typically include air pollution, noise, humidity, light, traffic etc. Individual sensors, on the other hand, entail citizens sharing personal data from their own devices. These can include location data from their smartphones, web traffic data, or even personal health data from wearables (see for example the salus.coop initiative). The main difference is that ambient sensors are defined as hardware and software technologies that fall beyond personal devices used by an individual (e.g. her or his smartphone).

Based on this distinction, it is noted that projects based on Production usually tend to entail a higher commitment and time for participating citizens to contribute. For example, the effort demanded for installing a sensor and sharing its data is arguably less if compared to a situation where citizens need to document their experience in a food environment through photography and text submissions like in the case of the Foodmapping project in Barcelona[43]. This implies that projects based on production of data need to dedicate significant effort to community maintenance and sustainability (in addition to community building also required in Access projects) in order to establish a valuable and meaningful data collection process and subsequent contribution. In this way, it can be argued that the type of data collection is linked with the actual structure and definition of the project whereby stable entities and permanent structures are more likely to achieve a long-term sustainability of the community of citizen scientists.

The type of data collection is linked with the actual structure and definition of the project whereby stable entities and permanent structures are more likely to achieve a long-term sustainability

4. Citizen Science Outcomes

The last dimension tackled in this document refers to the actual results of citizen science projects. As highlighted in section 2 above, evidence of citizen science contributions and impact span across domains and disciplines. However, it is crucial to reflect on what type of outcomes can be generally achieved, and how different types of outputs and outcomes can lead to different considerations

[40] AiguaBCN - ISGLOBAL https://www.isglobal.org/-/aiguabcn
[41] Surfing for Science https://www.asensiocom.com/surfingforscience/en/
[42] Saca la lengua https://www.sacalalengua.org/
[43] Ideas for change *Exploring eating environments and habits with citizen science* https://www.ideasforchange.com/en/archive-case-studies/foodmapping-en

about the overall projects or interventions. Based on existing reviews, citizen science projects can be positioned based on three possible outcomes: (1) informing public policies; (2) lead to novel scientific discoveries; and (3) raise awareness about a particular topic or issue.

4.1 Inform public policies

In several instances of citizen science projects, the (intended) ultimate goal is to inform policy making processes and/or to contribute to policy-related activities such as monitoring compliance to existing ones[44]. Existing literature and evidence from previous projects showcase difficulties in achieving these outcomes being primarily related to either the lack of rigid criteria to ensure appropriate quality and reliability of the data provided by citizen science[45], or to the lack of innovation capabilities and resources of the public sector, which is well acknowledged. In these cases, success factors revolve around engaging policy makers from the onset, to ensure both a clear positioning of the citizen science intended outputs in the current regulatory framework (and in future plans) as well as that the appropriate representatives are on board to guide the actions and processes in a way that is useful for policy making. Too often these efforts are undertaken (usually unsuccessful) starting from the actual results.

4.2 Scientific discoveries

Other citizen science outputs and results are leveraged for research, i.e. to underpin novel scientific findings[46]. These projects tend to prioritize the employment of rigorous scientific protocols and methodologies, and, for these reasons, they are often led by academic institutions such as universities or research centres. They vary from the previous type, in two main ways: first, results of these projects typically take the form of scientific reports or papers. While these may have other outputs associated (e.g. a dataset), the reports remain the main contributions. Second, these instances tend to be temporary in nature, i.e. following research methodology from the design of a research question to its answers.

4.3 Raise awareness

Other citizen science efforts aim at raising awareness about certain topics or issues. Usually, projects in this sphere lack the methodological rigor and scientific validity to be considered as reliable academic contributions or as a useful means to inform new policies. Rather, these aim typically at creating a first understanding of issues that are poorly addressed to date, hoping that more rigid and solid endeavours can be implemented for fostering either new research or policies depending on the

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[44] Hecker, Susanne; Bonney, Rick; Haklay, Muki; Hölker, Franz; Hofer, Heribert; Goebel, Claudia; Gold, Margaret; Makuch, Zen; Ponti, Marisa; Richter, Anett; Robinson, Lucy. "Innovation in citizen science–perspectives on science-policy advances". *Citizen Science: Theory and Practice*, Vol. 3, Núm. 1 (2018), pp.4-4.

[45] Balázs, Bálint; Mooney, Peter; Nováková, Eva; Bastin, Lucy; Arsanjani, Jamal Jokar. "Data quality in citizen science". *The science of citizen science*, Vol. 139 (2021), pp.978-3.

[46] Fontaine, Amélie; Simard, Anouk; Brunet, Nicolas; Elliott, Kyle H. "Scientific contributions of citizen science applied to rare or threatened animals". *Conservation Biology*, Vol. 36, Núm. 6 (2022).

topic. For instance, *#Cuentalo*[47] leverages citizen data for raising awareness about domestic violence to women.

Expected outcomes in citizen science projects require different planning and approaches, as well as priorities

We argue that different intended outcomes require different planning and approaches as well as priorities. For example, policy monitoring processes may require real time data and may put important constraints with respect to the standard adopted to enable interoperability with existing systems and services and the guarantee that the same data will be available under the same conditions in the future. Differently, projects devoted to scientific contributions may put more emphasis on the methodologies behind the collection and the rigid theoretical frameworks underpinning the data itself. They may require levels of transparency to ensure trustworthiness of the study and replication and re-use from other actors from the scientific community.

5. Conclusions and Looking Forward

This document provides an overview of citizen science and proposes some variables to be considered when approaching the field. We argue that the literature to date too often attempts to generalize methodologies, protocols, strategic insights and, more generally, theories around citizen science. However, citizen science projects, as outlined and exemplified in this paper can be of widely varying natures, and these should deserve reflections as they underpin different principles and strategies.

Citizen science projects are of widely varying natures, and these should deserve reflections as they underpin different principles and strategies.

In the introductory section of this paper, citizen science has been introduced as the result of several trends. These include the rapid evolution of information and communication technologies, complemented by growing visions of open science and knowledge and the increased push for societal participation in both scientific research and democratic processes and decision making. These contexts keep evolving rapidly. Looking forward, we expect that the continuous digital transformation across sectors and society, will keep driving citizen science avenues. We here discuss general digital transformation trends as outlined in Errandonea[48]: outlines four clusters of digital transformation trends that are currently changing several aspects of citizen science:

Deliberative Platforms: these more and more established IT-enabled innovations enable more and more active engagement of the public in democratic decision making. One of the most prominent examples refers to the Decidim Platform[49]. This is a two-sided platform where active interaction of citizens with public authorities is enabled, often with the scope of discussing and deliberating on certain issues. This digital space includes the possibility of the public to present ideas and carry out

[47] Proyecto #Cuéntalo https://proyectocuentalo.org/

[48] Errandonea, Lucía. *Exploring the impact of digital transformation on public governance - A community perspective*. Luxembourg: Publications Office of the European Union, 2023. ISBN 978-92-68-02567-3. doi:10.2760/679503.

[49] decidim.barcelona https://www.decidim.barcelona

advocacy for creating new services or improving existing ones[50]. Typical examples of concrete applications include but are not limited to Participatory Budgeting[51], e-Petitions in the UK[52], or defining priorities to be addressed by policy makers like in the case of Your Priorities in Iceland[53]. These trends hold the promise of changing the scope and outcomes of citizen science for policy making, addressing the existing gap that currently marks a clear separation between communities and public policy agencies. This, as argued in the beginning, is still one key challenge that the discipline as a whole is facing.

Social Media Platforms: the proliferation of social media and their more and more widespread use across society. The key contribution of this digital transformation trend refers to the possibility of communities to amplify both their size as well as their level and number of interactions among members, without the need of proximity between them. Existing platforms such as X, Instagram, Facebook, WhatsApp, among others, are more and more enabling communities to organize themselves and grow around a common scope or issue. Looking forward, the contribution seems clear and leading to concepts of bigger and, sometimes, more decentralized communities working together for a common purpose, or at least for different purposes underpinned by a common denominator[54].

Collaborative Platforms: somewhat in the middle between the two previous trends outlined, collaborative platforms emerge as online spaces that aim at "facilitating, enabling and to some degree regulating many-to-many collaborative relationships"[55]. The difference with the previous is in that they provide more structure if compared with social media, but still maintain ownership by the community if compared with deliberative platforms. The outcomes are somewhat similar in nature as these collaborative platforms typically enable joint decision making (like the former above) and allow for a more decentralized interaction among members as well as the growth in size of the community. Examples in this sphere include Change.org[56], crowdfunding platforms such as Goteo[57] or Kickstarter[58], or even specialized communities such as Open Food Network[59].

Sensing and Internet of Things (IoT) devices: the last digital transformation trend considered as impacting the future of community work, including citizen science, refers to the more and more

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[59] Open Food Network https://openfoodnetwork.org/

adoption and diffusion of sensing and IoT equipment that allow for more and more granular data generation about phenomena of interest, often in an automated manner. Systems typically go beyond data collection, and also include overall architectures for also store, retrieve and process this data[60]. This trend enables more and more communities to generate quality data to be used for different purposes, including policy advocacy, monitoring existing policies or even informing new ones. Looking forward, the potential of citizen science may be amplified by these capabilities, mainly in the form of enabling generation and management of data that is characterized with higher level of quality and credibility (i.e. less bias) if compared with more non-digital or previous generation systems.

Concluding, this paper provides an overview of the breadth of the citizen science discipline and discusses some ways to break down citizen science projects based on different variables that characterize them. While it is not the aim of this paper to provide an exhaustive taxonomy, we hope it can serve as an additional steppingstone to better understand and plan for future citizen science directions thus addressing its currently scattered landscape.

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