

# A PARTICIPATORY, MULTIDIMENSIONAL AND MODULAR IMPACT ASSESSMENT METHODOLOGY FOR CITIZEN SCIENCE PROJECTS

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## ABSTRACT

This paper presents a multidimensional methodology for assessing the scientific, social, economic, political and environmental impacts of citizen science (CS) projects. Besides these five areas of impact, the methodology considers also the transformative potential of the CS projects, i.e. the degree to which a CS project can help to change, alter, or replace current systems, the business-as-usual, in one or more fields such as science production or environmental protection. The methodology is designed to be modular and flexible so to adapt to the specificities of different CS projects and offers operational tools for its use by non-experts. The paper also describes the co-design process followed for its development and discusses the main lessons learned as emerged during its testing with 16 citizen science projects.

## 1. INTRODUCTION

The engagement of citizens in research, data collection, decision-making, capacity-building, and integration of local knowledge into science is becoming more and more relevant in the light of current debates on climate change, sustainability and transition, and the like (Sauermaun et al. 2020; Fritz et al, 2019). Indeed, citizen science (CS) initiatives are flourishing as a way to engage citizens in different phases of the scientific process (Bonney et al., 2009a) and the attention for this phenomenon is growing among researchers and decision-makers (Hecker et al., 2018; Vohland, K. et al. 2021).

The potential effects of citizen science are expected to be numerous: to tackle emerging social and environmental issues, empower local communities, promote behavioural change, support learning and skill acquisition (Rowland, 2012; Theobald et al., 2015). However, impact of CS is hard to measure and presents several challenges. Indeed, impact can vary considerably depending on the type and focus of CS projects (EC, 2018) and it is often multidimensional associating, for example, scientific impact with other kind of impact such as social or political ones.

Often citizen science projects' teams do not perceive the need to assess their impact or, more often, they do not have the time and/or

the competences for doing so (Kieslinger et al, 2017; When et al., 2021). Indeed, on the one hand CS projects are often characterized by limited resources (both in terms of human resources and time) and, on the other hand, competences from social science and humanities - that would be needed for developing ad-hoc impact assessment processes and carry them on in a systematic way - are not available in most CS projects focusing on natural science and other non-SSH disciplines (Tauginienė et al., 2020). Besides this, as shown by When et al. (2021), in their systemic literature review on the topic, most publications dedicated to CS impact assessment consider only one or two dimensions of impact. Additionally, only few publications provide actual indicators for impact assessment while the vast majority are at a higher level of abstraction, in this way, failing to provide a ready-to-use methodology for practitioners (Ibidem).

Moving from these challenges, we developed a multidimensional and fully operationalized methodology. The methodology here-after described, indeed, considers scientific, social, economic, political, and environmental impacts; each of these areas of impact is articulated in several dimensions for a total of 24 dimensions. Besides this, to address the challenge of the diversity that characterize CS projects, we designed the methodology to be modular, so that each CS project can select the areas of impact and dimensions that are more relevant for the project and focus only on those, in this way personalizing the methodology to the project's needs. Finally, we developed and tested specific indicators for each dimension and developed questionnaires and guidelines for data gathering offering ready-to-use tools for interested practitioners.

We did so by moving from other methodologies already available, first of all the work of Kieslinger, B. et al. (2017), Shirk et.al. (2012), and Haywood and Besley (2014), with the aim of: a) enriching the number of dimensions considered in each area of impact by combining different approaches b) make it fully operational for non-specialists of impact assessment c) develop a flexible and modular framework that allows personalisation but, at the same time, can be used for considering different CS projects at the same time (allowing aggregated analysis), d) adding a model for evaluating the transformative capability of CS projects, i.e. the possibility for them to propose an alternative way of doing science and engaging citizens in the scientific process at a systemic level.

The methodology here described was integral part of ACTION<sup>1</sup>, a project co-financed by the European Commission under the Horizon 2020 Research Framework. The project was run by a consortium of research partners and organisations with substantial experience in carrying out CS projects. The aim of ACTION, that lasted from February 2019 to January 2022, was to make citizen science more participatory, inclusive, open and citizen-led. It pursued this overall goal by carrying out two open calls that provided financial and mentoring support to 10 new and ongoing CS projects in the field of pollution. These projects – which participate to a multidisciplinary, six months, acceleration programme - added up to other six CS projects that were carried out by organisations already included in the ACTION partnership. Overall, 16 CS projects were supported; they focused on different kind of pollution, more precisely, air, water, soil, noise, and light pollution. Most of the projects lasted six months and were new projects, while four were longer, well-established projects. They vary considerably in terms of number of citizens engaged in scientific activities: overall they involved more than 1200 citizens: some of them worked with less than 10 volunteers, while others worked with up to 300 persons<sup>2</sup>. Finally, it is worth mentioning that out of the 16 projects, five were managed by teams belonging to academia (universities and research centres), while the other were led by associations, NGOs and grassroots organisations<sup>3</sup>.

The article is structured as follows: section two describes the participatory process followed for developing the impact assessment methodology and illustrates how to use it in practice; section three describes the areas of impact and dimensions considered with examples of the results obtained by its implementation, while section four discusses the main lessons learned and sets the scene for future research.

## 2. CO-DESIGN AND IMPLEMENTATION PROCESS

The ACTION impact assessment methodology has been developed following a co-design approach (Steen, 2013). The process started with an in-depth literature review focusing on papers dedicated to the topic of impact assessment in CS and on those analysing, more widely, the benefits or the impact of CS. The latter group of papers were used to map the reported benefits of CS and assure to provide guidance for analysing them from an impact assessment point of view in case these were not already covered by other methodologies. The literature review highly benefited from the work carried out by Kieslinger et al. (2017), and by When et al (2020a) and (2020b) that investigated in a systemic way the state of the art before us. Result from the literature review were combined with results of previous empirical research carried out by the authors (Passani et al., 2015) and led to the presentation to the ACTION consortium of a first draft of the impact assessment methodology.

This first draft included the five areas of impacts and several of the dimensions that are presented later in this paper. During a dedicated meeting, we gathered the feedback from project partners: four being organisations with experience in carrying out CS projects in the field of pollution and three carrying on research on CS and/or providing support to CS teams, especially in the field of open science. The feedback and comments collected suggested some specific changes to the dimensions to be considered. Besides, it clearly emerged that impact assessment was not a standard practice in CS projects, thus the necessity to provide more guidance on impact assessment overall and of a practical and step-by-step-based approach to its implementation. To answer these needs, we created an impact assessment canvas for CS projects as a first step of a larger how-to guide that has been developed throughout the project (described here after)<sup>4</sup>.

The impact assessment canvas is a four-pages visual document that, following the principle of the impact value chain approach (IMWG, 2014), guides CS project managers to think about the impacts of their project and navigate the ACTION impact assessment methodology while discussing to what extent the various dimensions are relevant for their project<sup>5</sup>. More precisely, the impact assessment canvas design is inspired by different business and impact canvas and adapted to the specificity of CS projects (Phillips et al., 2014; Ratto-Nielsen, 2017)<sup>6</sup>. It guides CS teams in making explicit the main issue that their project tackles, in mapping their main research question, their stakeholders, and the input, output, activities and expected impacts of their project. In the last page, then, the areas of impact and the dimensions of the methodology described in section three are listed and CS teams are requested to rate the relevance of each area of impact and of each dimension.

The impact assessment canvas is not only the output of the first co-design step of this methodology but became a crucial tool for its further development and for its application. Indeed, the canvas was provided to the CS projects supported by the first edition of the ACTION acceleration programme; they filled it in and provided feedback through one-to-one interviews. The feedback helped us in mapping what aspects of the canvas and of the proposed methodology were not clear, which ones were perceived as most relevant and what was missed. This provided input to the next version of the ACTION impact assessment methodology<sup>7</sup>. The same process was then followed with the CS projects supported by the second edition of the ACTION acceleration program. Beside this, the methodology was presented extensively not only in scientific conferences, but also to other EU funded projects supporting or carrying out CS activities. These exchanges helped us in refining the methodology. Finally, the methodology was applied to the 16 CS projects supported by ACTION, and this provided additional feedback that we incorporated in the latest version of the impact assessment canvas and are reflected in the methodology presented in the following section.

Participation from CS projects was crucial, not only in designing the methodology, but also for its implementation. Indeed, once the projects

1 [www.actionproject.eu](http://www.actionproject.eu)

2 In talking about engagement in scientific activities (Bonney et al., 2009a) we refer to the various steps of a participatory research project that goes from problem framing to impact-oriented activities passing by data gathering, analysis and interpretation (Passani et al., 2020a).

3 More detailed information on the CS projects mentioned in this article can be found at: <https://actionproject.eu/citizen-science-pilots/>

4 Practical information on how to use the methodology described in this paper are available in the ACTION toolkit at the following link: <https://actionproject.eu/toolkit/> in the section dedicated to impact.

5 At the following link the ACTION impact assessment canvas: <https://www.zenodo.org/record/5930525#Yotz8WBxBxp>

6 Other source of inspiration have been: <https://www.artsculturefinance.org/wp-content/uploads/2018/09/Impact-Management-Canvas.pdf> and <https://www.threebilly.com/sustainability-impact-canvas>

7 This version of the methodology takes on board also the suggestions that emerged during the first project review meeting held in June 2020

filled in the canvas, a dedicated meeting was held with each of them to go through it together, validating the results, and design the impact assessment data gathering process. After we defined together the dimensions to be analysed thanks to the canvas, we discussed with each team who to involve in the data gathering process (only the CS team, also the volunteers, other project's stakeholders), the timing of the data gathering and the best instrument to be used (online or paper-based questionnaires, focus group, etc). The fact that each CS project can select the focus of its impact assessment and the possibility to personalize the data gathering process and timing represents the main elements of modularity of our methodology.

The implementation process of the methodology here after described, therefore, envisages the following steps:

1. Fill in the impact assessment canvas for starting a reflexivity process on impact and select the most relevant areas of impact and dimensions.
2. Plan the timing of the impact assessment and the stakeholders to be involved. For supporting this step, we developed another tool, called impact assessment matrix, which lists the different variables for each of the impact dimensions, and advises who needs to supply the data (project managers and/or citizens/vol-

unteers), and when (only at the end of the project (ex-post), or also at the beginning (ex-ante)).

3. Carry out the data gathering using or adapting the questionnaires provided.
4. Analyse the data and develop and impact assessment report.

The process and links to the different support tools are reported in more details in Passani and Janssen, 2022.

## 3. THE ACTION IMPACT ASSESSMENT METHODOLOGY

As mentioned in the previous section, the methodology considers five areas of impact: scientific, social, economic, political and environmental. It also considers the transformative potential of the citizen science projects. Each area of impact is articulated in several dimensions: 24 overall (Figure 1). Each dimension is operationalised in different variables. The methodology is quali-quantitative: each dimension is operationalised considering how well it can be expressed in numerical or non-numerical terms following a mixed-method approach (Tashakkori et al., 2010a).



**Figure 1** ACTION areas of impact and dimensions

The dimensions considered are described in the next subsections. For more detailed information on the main variables/indicators/methods used for the assessment please refer to Passani et al., 2021.

### 3.1 SCIENTIFIC IMPACT

Scientific impact is one of the most important areas of impact for a citizen science project. It is, indeed, included in every impact methodology of citizen science (Bonney et al., 2014 and 2009; Haywood and Besley, 2014; Jordan et al. 2012; Phillips et al., 2014, and 2018; Tulloch et al., 2013), even if the exact interpretation or measures differ. Our methodology comprises four subdimensions for scientific impact: scientific

knowledge, new research fields and interdisciplinarity, new knowledge resources, and innovation in education. The first three mimic the work of Kieslinger et al. (2017), which in turn is influenced by Bonney et al. (2009a and 2009b). Compared to these earlier methodologies, we made three adaptations. First, we added a dimension: innovation in education. This adaptation was the result of the participatory process with a citizen science project that focused on using citizen science methods in secondary education: "Students, air pollution and DIY sensing<sup>8</sup>". This project had a clear impact on innovation in education, in the sense that they brought innovative methods to the standard school curriculum (Grossberndt et al., 2021). While this impact is related to social impact on learning, innovation in education specifically refers to innovation in the methods of education, rather than impact on what people learn.

Second, within the dimension “scientific knowledge” we added special attention to the topic of open science by assessing the openness and FAIRness (Wilkinson et al., 2016) of the collected data. We added this to reflect the focus on open science in science policy (Moedas, 2018), which was also a focus of the ACTION project.

The third adaptation that we made is to add interdisciplinarity as an explicit part of new research structures (the second dimension). We agree with Crain et al. (2014), that citizen science has substantial potential to increase the interdisciplinarity of science. In general, many citizen science projects are already interdisciplinary in nature. But especially when we look at citizen science projects with an environmental focus (which was the case for ACTION), integrating a natural science perspective with a social perspective is at the core of these projects.

### 3.2 SOCIAL IMPACT

As stated by Hecker and al. (2018, p.7), CS can also have an important impact at the social level: “Citizen science can [...] positively influence society by providing opportunities for learning, empowerment, enjoyment of nature, social engagement or enhanced scientific capital”.

In line with this, Kieslinger et al. (2017), suggest evaluating these elements both at the individual level, by considering the impact of CS on citizen scientists/volunteers and at the societal level. With reference to the impacts at the individual level they consider impacts in terms of acquisition of new knowledge, skills and competencies, attitudes and values and behaviours and ownership. These three dimensions are included in our methodology and an operationalisation of each of them, based on several sources, is provided. At the social level, they consider civic resilience, social cohesion and specific social impacts related to the topics covered by individual CS projects. These topics are present in our methodology too but are framed in a different way based on our experience in previous projects (Passani et al., 2015; Nurmi et al., 2017). Indeed, we consider the impacts on communities, especially looking at the capability of CS projects of promoting social inclusion and cohesion, community empowerment and the increment in social relationships among participants, within the research community and among local stakeholders. This focus on community moves the analysis of social impact at its meso level, living the macro level better covered in the political impact area.

A detailed description of the definition and literature background of each of these dimensions can be found in Passani et al., 2020. Here after we introduce only those aspects that could be considered innovative if compared to state of the art in CS impact assessment. These are: community empowerment, social inclusion and impact on way of thinking, attitudes and values.

An empowered community is a community able to act towards a common objective and to promote the desired change. Within this dimension we map the community created by a CS project, the number of members, the level of interaction among them and the improvement in terms of bonding, bridging and linking social capital (Putman, 2000; Healy and Cote, 2001). Another element of social capital that is considered is the level of trust among community members (Putnam, 2000), which is shown to have an important role in community agency and also in individual commitment in pro-environmental actions (Meyer and Liebe,

2010). We also analyse how participating in the CS activities might influence the perceived efficacy of participants, i.e. the perception of being able to learn a specific content, to perform a specific behaviour and to act towards a defined goal (Bandura, 1982). Self-efficacy affects individuals’ decisions, behaviours, and persistence in activities and is therefore an interesting element to be studied as an enabler of behavioural change too (Bandura, 1982 and 2000; Schunk, 1991; Healy et al., 2001).

The aspect of inclusiveness considers projects’ capability to engage people of different ages, genders, cultural, educational and economic backgrounds and people belonging to categories at risk of social exclusion and/or discrimination. On this it can be noticed that at least five out of the 16 projects examined were able to be inclusive: the Water Sentinels<sup>9</sup> project, for example, collecting water pollution data, was able to engage the local fishery community that is characterized by low level of formal education, while Sonic Kayaks<sup>10</sup> worked with people with vision impairment.

Considering now “impact on way of thinking, attitude and values” we investigate the projects’ impact on participants’ opinions and attitude using two complementary approaches. A pragmatic one based on self-assessment and a more research-oriented one investigating the citizen scientists’ opinions and attitudes towards the environment and science before and after the participation to a CS project. The interest of the latter approach is based on, among others, Straughan and Roberts (1999) that argue that psychographic characteristics, such as citizens’ attitudes, interests and opinions, are the most important variables in predicting green and pro-environmental behaviours. In investigating psychographic characteristics of participants according to their environmental concerns at operational level, we refer to the New Ecological Paradigm Scale Items (NEPS) (Dunlap et al., 2000). In considering opinion and attitudes towards science we refer to the (M)ATOSS approach (Brossard et al., 2005). Ideally the two approaches should be used in synergy, but is important to notice that the second approach, which requests to gather more data and in two different moments (before and after the CS project implementation) shown to be more challenging for most of the CS projects we have been working with.

### 3.3 ECONOMIC IMPACT

Economic impact is not the principal goal of citizen science projects and in the assessment carried out with the present methodology it was perceived as the less relevant by all the analysed projects. Nevertheless, it is not irrelevant, and the time invested by citizens in gathering data and, sometimes, in curating and analysing them has a clear economic value.

Blaney et al. (2016) offer a good starting point for assessing economic impact of citizen science projects. They consider and discuss strengths and weaknesses of 9 methods, both quantitative and qualitative including Replacement Value, Cost-Benefit Analysis (CBA), Return on Investment (ROI), Social Return on investment (SROI), multi-criteria analysis (MCA) and others. All these methods share the characteristics of expressing the economic impact of a CS project with a single value (being monetary or not) that summarises various impacts, including social ones.

For our impact assessment methodology, however, we wanted to propose a modular methodology to CS stakeholders in which each area of

9 <https://actionproject.eu/citizen-science-pilots/water-sentinels/>

10 <https://actionproject.eu/citizen-science-pilots/sonic-kayaks/>

impact can be assessed separately. Consequently, we did not apply the above-mentioned methods. Instead, based on our initial insights into the projects supported by ACTION, as well as their feedback, we consider the following dimensions: impact on employment, cost saving, income and revenue generation for leading organisations and economic impact on the local communities.

The second dimension, cost saving, deserve a closer look. It analyses to what extent a CS project can produce cost or time saving for researchers or local stakeholders, for example a Municipality, by carrying out activities that would be otherwise more expensive or impossible to perform. We moved from the work by Blaney et al. (2016) and simplified it in order to reduce the amount of information to be provided by CS project teams. Three of the projects considered show positive impact in this sense; one of them, ReStart<sup>11</sup>, engaged volunteers in curating data related to electronic waste. Volunteers dedicated 150 hours to the project, generating a value of 2,820 Euros, while the number of hours dedicated by the project team to citizens' engagement and support was equal to 40, corresponding to approximately 752 Euros. In this sense the cost saving for the team is positive, showing the good potential, in terms of time/cost saving, of applying microtask techniques in CS projects as done by the team.

### 3.4 POLITICAL IMPACT

Political impact refers to the transfer and uptake of knowledge and results from citizen science in political processes and actions. Political processes and actions include policy processes (motivations, rationales and priorities, design, implementation, and monitoring), empowerment of citizens to participate and self-organise, and political support for citizen science. Political impact of research occurs "when knowledge is transferred, that is, when decision-makers and/or social actors employ the published and disseminated results as the basis for their policies and/or actions" (Reale et al., 2018, p.300).

Other impact methodologies do not specify political impact or include it as a part of societal impact (Kieslinger et al., 2017). We opted to include it as an important dimension, because from the literature, it is clear that citizen science does have this potential: it engages with political processes in several ways and can thus generate different forms of political impact (Göbel et al., 2019; Turbé et al., 2019; Roger et al., 2019; Hecker et al., 2019).

This potential was reflected in the participatory process with many of the citizen science projects that we worked with. In our initial phases of collaboration, political impact appeared as an important aim of the projects, and indeed by the end of our assessment, 13 out of 16 projects showed political impact. One project for example, NoiseMaps<sup>12</sup>, empowered citizens with an evidence-based voice to contribute to policy agenda setting, and to collaborate with the municipality, by recording sound pollution in the citizens' neighbourhood. In addition, they increased political support for citizen science through positive collaboration with the city council in Barcelona.

### 3.5 ENVIRONMENTAL IMPACT

Environmental impact considers how the project can contribute to the conservation of natural assets, support pollution reduction or have another positive impact on the environment (McKinly et al., 2017). The ways in which a project can achieve this impact varies from providing scientific knowledge to inspiring social and political action. In this sense, environmental impact can be achieved in tandem with most of the other dimensions in the impact assessment methodology. However, because of its importance, especially in the field of pollution, and its expected future importance given the climate challenges we face, we chose to give it more prominence in the ACTION methodology than, for example, Kieslinger et al. (2017).

In this methodology, environmental impact is measured with methods that are adapted to the citizen science project in question. When reflecting on this dimension with the citizen science projects, we realised that the environmental impact of each project is so diverse that we cannot provide one method, and that often, these measurements will have to be done by the citizen science projects themselves.

### 3.6 TRANSFORMATIVE POTENTIAL

This dimension assesses the transformative potential of a project in its context, i.e. the degree to which the project can help to challenge, alter, or replace dominant institutions and structures. A project has transformative potential by being radical, iconic, catalysing, timely, and by allowing for learning. Improving these aspects would increase the chance that this project will have long-term and long-lasting effects on society. As Hölscher et al. (2020) put it, the transformative potential of an innovation "is visible in the extent to which it questions, changes or challenges (elements of) dominant regimes (e.g. user behaviour, technical components, market structures)" (p.25).

We see citizen science as an innovation that has the potential to change how science is currently practised. As Turrini et al. put it: "the development of more citizen science formats that involve the public into the whole scientific process could foster innovation at a systemic level" (2018 p.184, see also Fernandez-Gimenez et al., 2008; Jordan et al., 2012 and Bela et al., 2016). This potential would not be captured by existing methodologies, nor by other existing impact methodologies, because this impact is achieved collectively – as part of a movement – and on a longer term.

This potential to change the scientific system is linked to the scientific impact indicators, especially those that focus on changing the institutional structures of academia. But citizen science also has the potential to transform other systems, such as the energy system, mobility system, or problem complexes such as biodiversity protection, because of the participatory way that citizen science is set up. To exploit and assess this potential, we use a methodology from the SIC Public Sector Innovation Blog<sup>13</sup> that focuses on five subdimensions, see Figure 2. In this figure we also see the questions that allow us to assess these sub-dimensions.

11 <https://actionproject.eu/citizen-science-pilots/restart-data-workbench/>

12 <https://actionproject.eu/citizen-science-pilots/noise-maps/>

13 <https://www.silearning.eu/wp-content/uploads/2017/04/6.transformative-impact-tool.pdf>

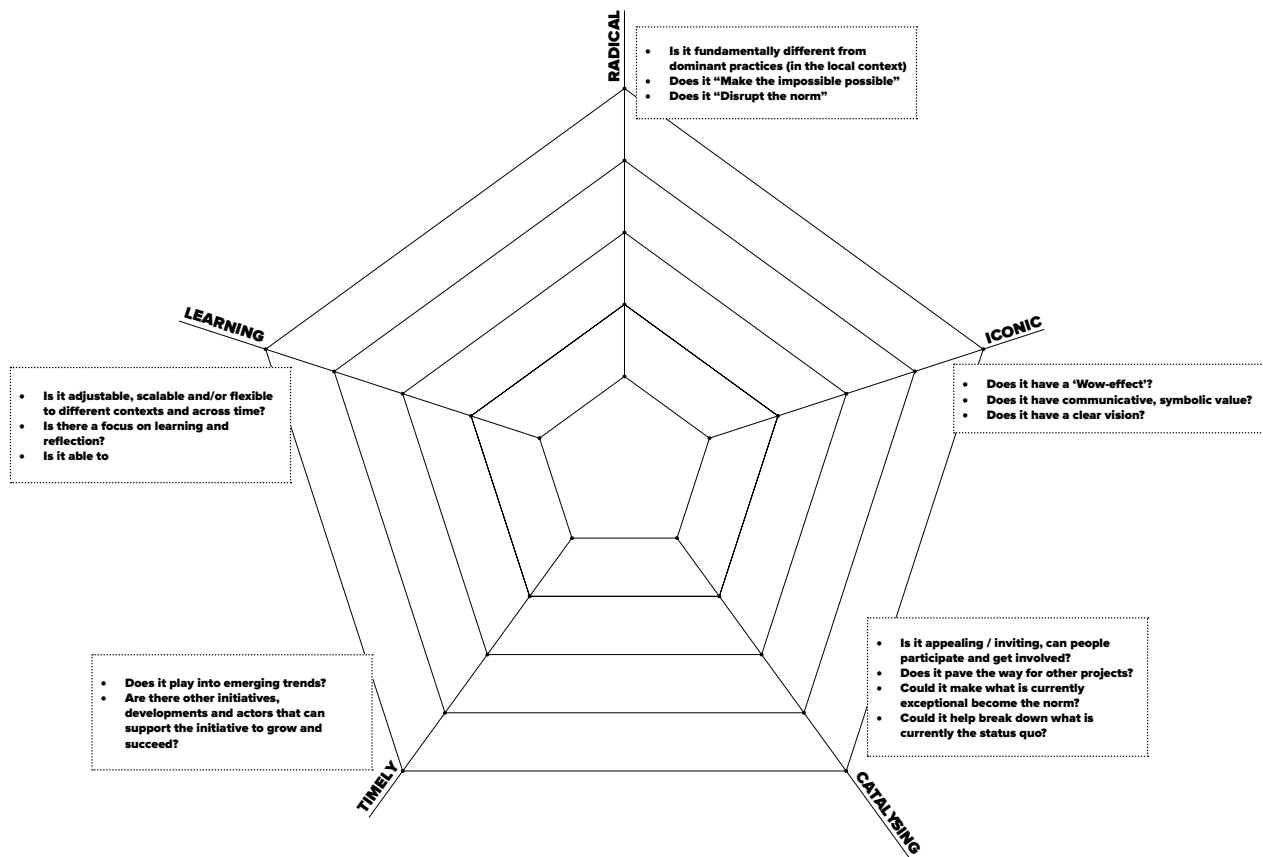


Figure 2 Framework to assess transformative potential, SIC Public Sector Innovation Blog

## 4. REFLECTION AND LESSONS LEARNED

In this article we presented the impact assessment methodology developed during the ACTION project, which is multidimensional, modular, fully operationalised and participatory. It is multidimensional because it considers scientific, social, economic, political, and environmental impacts and articulates these areas of impacts in several relevant dimensions. It is modular because each area of impact and each dimension can be analysed separately according to the characteristic and the needs of different CS projects. It is fully operationalized because each dimension is linked to specific indicators and because the overall methodology has been designed with the aim of enabling CS teams to carry out their impact assessment in an autonomous way. For this reasons data gathering guidelines and tools have been designed, tested, and released openly to facilitate their uptake. Finally, it is participatory in two ways: it was co-designed with citizen science projects and can be implemented by citizen science projects by involving different stakeholders such as citizen scientists/volunteers and other organisations.

While doing an impact assessment is still a challenge for citizen science projects because of a lack of time and/or resources, we believe that the presented methodology tackles important methodological challenges by extending existing methodologies and by providing an operationalisation supported by practical and flexible tools such as the impact assessment canvas and the related questionnaires.

We end the article with some reflections and lessons learned. We observed that the impact assessment methodology responds to the needs of citizen science projects: it allows them to translate their impact in terms that policy makers, potential funders, and other interested parties can understand. The time investment needed to perform an impact assessment still proved challenging for some projects, especially when impact on many dimensions was expected. We saw that this challenge was eased when we substituted interviews for self-reported questionnaires. This allowed the projects to better plan their work and, still, measuring many dimensions can result in long questionnaires, which some project teams found hard to find time for.

The effort needed for answering questionnaires should be evaluated carefully also when asking citizen scientists/volunteers to do so, indeed it is important to find a balance between the need of data and the need to protect volunteers from exploitation. Indeed, volunteers are already asked to do a lot in the citizen science projects themselves, and for some project managers, asking the volunteers to fill out questionnaires for the impact assessment felt like over asking. We responded to this by designing questionnaires that could be filled out by the project managers themselves, estimating as best as possible the impact the project had on their volunteers. When the project managers work closely with the volunteers, we saw that this approach is valid. However, for future applications, it would be helpful to think of ways to make data collection with volunteers easier and less time-consuming, for example

developing multiple, but very short online surveys, or by making the impact assessment part of the project design from the very beginning and engaging volunteers in group interviews or other more social and interactive moments.

Additionally, we observed a training effect of the impact assessment procedure for the project team. It did not only serve as a means for impact assessment, but also induced reflexivity: it allowed the project teams to reflect on what impact they could achieve and how to do so. Interacting with the impact assessment canvas helped several projects in realising that they could - for example - be more inclusive and this led to re-design their activities in order to reach this impact. An avenue for future development is to make this training effect more explicit and to develop methods for reflexivity to be implemented during a citizen science project.

Furthermore, when designing and applying the methodology together with the citizen science projects, we noticed that there can be a substantial difference in impact between small and large projects. Large projects, especially when they engage many volunteers, show a big impact, while for smaller projects with less participants the impact is less easy to capture. The way we designed the methodology, its quali-quantitative nature, and especially its flexibility and modularity allowed us to track small as well as larger impacts. For example, one of the participating projects had only five volunteers, but because we could adapt the methodology to their specific situation, we were able to see that they had social, political, and transformative impact, more specifically on social inclusion and policy processes. Especially the transformative potential dimension allows us to capture impact from small projects on a longer term, and impact that is achieved collectively, as part of a movement. For example, while small projects will not 'change the world' immediately and on their own, if their project is radical and iconic, they can prefigure new practices, and play a part in deep changes as part of a collective movement.

We were not able to measure environmental impact. While this seems like an important dimension of impact for citizen science projects, especially in the field of pollution, there should be future research on whether this dimension belongs in an impact assessment methodology, and if so, how it should be measured. We suspect it is easier to measure environmental impact over a longer period; indeed, it showed to be an indirect impact of CS projects that, while supporting policy innovation and behavioural changes among citizens could become visible in the long run.

Finally, for future research, it would be interesting to better investigate how impact is generated and what are the characteristics of a CS project that can influence the achievement of certain impacts. For example, it would be interesting analysing to what extent the academic or non-academic "nature" of the CS management teams is linked to specific impacts or if other characteristics, such as the disciplines represented in the team or the relevance of online interactions versus face-to-face interactions with volunteers, or the level of engagement of citizens in different phases of the research process can play a role in achieving different impacts. The methodology here described could support this kind of analysis, but a larger sample of CS projects would be needed so that these reflections provide avenues for further development and research.

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### **KEYWORDS**

citizen science, impact assessment, transformational potential, co-design, lessons learned