54

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SPECIAL ISSUE

PARTICIPATORY EVALUATION AND IMPACT ASSESSMENT IN CITIZEN SCIENCE

ANTONELLA PASSANI, ANNELLI JANSSEN, KATHARINA HÖLSCHER, GIULIA DI LISIO

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

L. D'ANDREA, E. KALPAZIDOU SCHMIDT, E. BUŽAN, M. VIDAL MERINO, E. DALL, C. COLONNELLO, E. K. GRAVERSEN, J. CERRI, L. IACOLINA, F.FEUDO

EVALUATING CITIZEN SCIENCE INITIATIVES THROUGH A CITIZEN SCIENCE-BASED APPROACH

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GOODBYE AND HELLO – THE FTEVAL JOURNAL GOES DIGITAL!

DEAR READERS OF THE FTEVAL JOURNAL,

This is the last printed issue of the fteval Journal for Research and Technology Policy Evaluation. It contains eight exciting articles dealing with participatory methods in the evaluation of Citizen Science, which have been reviewed by selected experts from the field. The editors of this special issue are Katja Mayer, Barbara Kieslinger, Teresa Schaefer and Stefanie Schürz from the Centre for Social Innovation (ZSI). The booklet was developed and realised in cooperation with the CoAct project [coactproject.eu]. We would like to thank them and the peer reviewers for their excellent cooperation.

The spectre of inflation unfortunately also affects the printing and mailing costs of our journal. We have therefore decided to redesign it as a digital-only publication and focus more on content development. In future, therefore, you will be able to download the fteval Journal and each individual article online.

However, you are always welcome to contact us with ideas and suggestions!

We thank you for your loyalty and your long-standing interest in our publication. If you are already a subscriber to our newsletter, you do not need to do anything else. You will receive the digital journal and will be notified when a new issue is published. If you have any questions about this or would like to inform us of a change in your e-mail address, please write to us at office@fteval.at. Your subscription will of course remain free of charge in the future.

Best regards and enjoy the current issue!

Klaus Schuch & Isabella Wagner

14 September 2022

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TABLE OF CONTENTS

EDITORIAL

PARTICIPATORY EVALUATION AND IMPACT ASSESSMENT IN CITIZEN SCIENCE

KATJA MAYER, STEFANIE SCHÜRZ, BARBARA KIESLINGER AND TERESA SCHAEFER
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In this issue of FTeval Journal, we approach the topic of evaluation in Citizen Science from a particular angle, inquiring about the possibilities and conditions for making evaluation more participatory than it has been to date. While Citizen Science is by definition highly participatory, this claim often does not extend to its evaluation and impact assessment practices. In this special issue, authors explore a few of the manifold potential entanglements of participation and impact assessment. They deal e.g. with the question which formats of participation can be useful for the evaluation of Citizen Science, and to which extent. Contributions range from theoretical discussions to praxis reports and detail existing approaches to participatory evaluation that involve participants of Citizen Science activities in reflecting and assessing projects' or initiatives' processes and outcomes. Before diving into a more detailed description of the focus of this issue and outline the individual contributions, we must briefly outline the problem situation.

The term Citizen Science refers to scientific work undertaken by non-scientists, often in collaboration with professional scientists in the context of research projects. The participation of citizens in scientific projects can take many shapes, such as identifying a research question, collecting or analysing data, monitoring environmental or health conditions, and more. Citizen Science is rooted predominantly in the natural sciences – especially in the field of biodiversity research – and the public health sector (Bonney et al., 2009; Del Savio et al., 2016; Haklay, 2015), but is increasingly adopted as an approach across disciplines (Heinisch, 2019; Pelacho et al., 2021). The social sciences have always exerted a major influence on the understanding of Citizen Science, which draws on its own long tradition of participatory research. Thus, participation in Citizen Science covers research approaches that explore as well as influence natural, technical and social realities in partnership (Unger, 2014). Such an understanding of participation emphasises the co-creation and democratisation of scientific knowledge production in order to find solutions closer to the concrete needs and concerns of society (Felt & Fochler, 2008; Irwin, 1995; Mayer et al., 2018).

As a result of the increased public funding of Citizen Science, the question of its impact has also moved closer to the centre of public interest. There are high expectations – especially in innovation policy – of the new insights that can be gained by the co-design of research with the participation of citizens and non-scientific organisations. While a fundamental reputational gain of Citizen Science is observed, there is still a wide gap between the ascribed potential at strategic level and the actual implementation, as well as the actual integration of results from Citizen Science into concrete socio-political or socio-ecological decision making (Bonn et al., 2022). Observers thus see the danger of overselling when it comes to promises to society as opportunities for participation in the scientific process are currently perceived as rather limited (Dickel et al., 2020). The question remains how a sustainable, responsive, and participatory research culture, as is also called for in the context of responsible research and innovation (RRI), can be achieved with Citizen Science (Maasen, 2020; Stilgoe et al., 2013).

While designing an evaluation concept for a Citizen Social Science project in 2018 and searching the literature for appropriate approaches, we were somewhat surprised to find very little empirical reports on participatory evaluation methods in the field of Citizen Science. This was a double blind spot: participation was neither a focus nor a method in evaluation. But the issue is considerably more far-reaching than that. It is only relatively recently that the term Citizen Science has been included in the indexing catalogues of scientific disciplines, such as those used by funding institutions. Thus, it is only slowly becoming possible to grasp the extent of Citizen Science projects in general. Furthermore, the systematic assessment of co-created methods, outcomes, and their impacts is generally very difficult (Milat et al., 2015), and there are few widely accepted and appropriate measurement methods (Bornmann, 2013; Spaapen & Van Drooge, 2011). Furthermore, indicators for Citizen Science in general and their social impact are only slowly being developed (Wehn et al., 2021), which in turn deal only marginally with participation. To properly evaluate Citizen Science and its impact, it is first necessary to consider scientific processes as part of a larger context in which different logics are at work. Thus, in addition to research design, data handling, and communication of results, not only do the various cultures of the disciplines exert a strong influence on research activity, but institutional ties, funding structures, and cultures of recognition play a major role as well. In a research system that defines performance primarily in terms of citations in scientific journals, societal relevance is not of central concern. Further problems therefore relate to the lack of incentives and recognition for the evaluation of participatory approaches in science and the difficulty of presenting such co-created results in traditional high-quality / high-impact publication formats, coupled with a lack of opportunities to adequately acknowledge the contributions of co-researchers (Bonn et al. 2022, p. 75). Last but not least, the possible forms of participation differ greatly in their characteristics as well as the associated formats and limits of knowledge production (Shirk et al., 2012).

We have been witnessing a change in the mainstream culture of research evaluation for some time now, shifting from a pure focus on the assessment of the scientific quality of results and orienting much more towards processes and stakeholders (Hemlin & Rasmussen, 2006). Accordingly, evaluation is increasingly seen as a learning process that supports self-reflection and adaptive management while helping to understand what impact Citizen Science initiatives have on science, involved citizens, and their socio-ecological contexts. Still, a review of the literature on evaluation (Schaefer et al., 2021; Svensson et al., 2018; Wehn et al., 2021) shows that in the field of Citizen Science as well as Social Innovation, participation in evaluation is mostly understood as "contributory". That is, information is collected from and sometimes by participants, but they are not actively involved in decisions about evaluation design and outcomes. Moreover, the body of scholarly literature is replete with criticisms of strictly pre-structured sets of criteria and targets, as well as urgent calls for further research on the topic (Milley et al., 2018; Wehn et al., 2021).

At the same time, there are other fields more or less adjacent to scientific research that can already draw on a wealth of experience in far-reaching participation in evaluation. One area in which participatory models have been used for a long time is programme evaluation. Success and quality control, as well as the assessment of the further effectiveness and sustainability of, for example, education programmes, rely heavily on collaborative or developmental approaches to evaluation (Cousins et al., 1996). Programme evaluation in education and youth work has already become much more participatory over the years (Richards-Schuster & Plachta Elliott, 2019). From these fields we know the advantages and strengths of participatory evaluation, which we hope to also establish for Citizen Science: identification of locally and thematically relevant evaluation questions, improvement of accuracy and relevance of reports, establishment and explanation of causality, improvement of project processes, organisational learning and capacity building, empowerment of participants, community- and team building[1]. Participatory evaluation is particularly suited to include notoriously neglected aspects of Citizen Science processes, such as trust building and power relationships (Bryson et al., 2011; Prainsack, 2014). Participatory evaluation schemes have to be assembled according to the project goals and the participants' expectations, but also have to be flexible enough to meet changes in the dynamics of participatory research routines. The challenge therefore is to plan accordingly, to develop the necessary skills for facilitation and incentive structures for such inclusive evaluation settings, so that assessment is not left to the project end, but actively implemented from the beginning of the research design. As such, participatory evaluation places its focus and uses time resources differently than traditional evaluation approaches, to negotiate questions of learning and accountability without going beyond the project scope. Milley et al. (2018) therefore suggest a move away from heavily indicator- and method-centred approaches. The focus should instead be on the flexibility of the evaluation process and the soft skills needed for the mediation processes. This special issue is dedicated to exactly these urgently needed soft-skills that can only be built by learning from a wide range of experiences. In our research and outreach activities, we encounter great interest in participatory methods for evaluation in Citizen Science from academics and practitioners alike. The diversity of topics and methods in Citizen Science, as well as the different research and funding cultures, do not make it easy to find quintessential examples here. We have to look beyond the disciplines and seek exchange among colleagues to share common problems, challenges, and potential solutions. Thus, the contributions from at times vastly different fields serve to break down the scientific silos, enable a cross-pollination between fields and methods, demonstrate possibilities, and discuss the necessary frameworks for more participation in evaluation based on concrete experiences.

The call for papers for this special issue aimed at a broad target group. On the one hand, we invited contributions from Citizen Science, participatory social research, public policy, environmental justice, public health and related fields. On the other, we also called for reports from practitioners, as well as theoretical and practical perspectives from programme evaluation and various other professions and disciplines. As a result, this special issue assembles a wide range of frameworks and methods for participatory evaluation, informed by the experiences gathered in diverse fields such as biodiversity, health, social policy, urban planning and so forth. Authors were invited to elaborate on theoretical and practical grounds their experiences with participatory evaluation in Citizen Science or other fields. We encouraged them – where applicable – to reflect on challenges, risks, and pitfalls, especially in times of physical distancing and global crisis.

We – Barbara Kieslinger, Stefanie Schürz, Katja Mayer and Teresa Schaefer – kick-off the special issue with our own paper, as our forays into participatory evaluation in the context of the EU-funded research project CoAct on Citizen Social Science inspired this publication (www.coactproject.eu). CoAct's participatory research is co-designed and directly driven by citizen groups sharing a social concern. The focus is on the development of methods to give citizen groups an equal 'seat at the table' through active participation in research, from the design to the interpretation of results and their transformation into concrete actions, as well as their evaluation. Together with our partners, we evaluated three research and innovation actions on the topics of mental health (Barcelona), youth employment (Vienna) and environmental justice (Buenos Aires). In the paper, we outline our approach to co-evaluation, present first results, and discuss challenging experiences. Our approach was guided by a previously developed 3-dimensional evaluation framework for Citizen Science (Kieslinger et al., 2018), which we adapted during the course of the project. Furthermore, we discuss the challenges of trying to adapt and extend this framework in a participatory way in times of Covid. Even though not all original co-evaluation plans could be implemented in the CoAct project, we can clearly state that the participatory evaluation approach was worthwhile. We were able to document important negotiation processes for defining the success of the project, the collaborative evaluation of participation, and the management of expectations. This provided continuous feedback into the research process, which helped the project succeed – especially in times of crisis.

1 This list is an adaptation from https://www.betterevaluation.org/en/plan/approach/participatory_evaluation (1 Sept 2022)

In their article, Ana Margarida Sardo, Sophie Laggan, Elke Franchois and Laura Fogg-Rogers report from the WeCount project (https://we-count.net/). WeCount engaged citizens to gather knowledge about traffic and mobility in their local neighbourhoods in 5 European cities (Leuven in Belgium; Madrid/Barcelona in Spain, Ljubljana in Slovenia, Dublin in Ireland, and Cardiff in the UK), using low-cost sensory equipment. The paper demonstrates a shift in Citizen Science design towards increased participation and co-design, putting citizens at the centre of decision making. As part of its evaluation framework, the project implemented co-creation and policy workshops centred on the question of how citizens wanted to shape the project to address their transport and mobility concerns. Detailing these approaches to evaluation, the paper interrogates to what extent the methodologies were able to involve citizens not only in participatory monitoring but also in evaluation. The authors point to the fact that the involvement of citizens in the evaluation process would not only help to identify priorities, but also develop a theory of change that integrates the needs for capacity building to implement collaborative assessment activities.

Similarly, Antonella Passani, Annelli Janssen, Katharina Hölscher and Giulia Di Lisio ask in their article whether the impact assessment framework developed in the Action Project (https://actionproject.eu/) can address both the demands for more participation and the negotiation of higher-level, policy-relevant impacts. The authors start from the question: how can we evaluate Citizen Science projects in a way that can show policymakers, funding agencies, and other stakeholders the impact of the project, while doing justice to the specifics of the participatory process, including e.g. the budget- and time-constraints of those involved in it? The ACTION impact assessment framework has a modular design and measures scientific, social, economic, political, and environmental impact, as well as the transformative potential of the project. The framework is based on collaborations with 12 Citizen Science projects over the last years. Several co-designed data gathering tools allow scientists and citizens to measure and discuss project outcomes collaboratively. The paper describes the process of developing the impact assessment framework, as well as its implementation to reflect the benefits and constraints and outline future needs, such as making data collection with volunteers easier and less time-consuming.

In their praxis report, Luciano D'Andrea, Evanthia Kalpazidou Schmidt, Elena Bužan, Mariana Vidal Merino, Elke Dall, Claudia Colonnello, Ebbe K. Graversen, Jacopo Cerri, Laura Iacolina and Fabio Feudo address the complex nature of evaluation tasks in Citizen Science by reporting their experiences from setting up the evaluation process in the Step Change project (https://stepchangeproject.eu/). Step Change draws on the experiences from five Citizen Science initiatives in different research fields (health, energy, and wildlife monitoring) and countries (Germany, Italy, Slovenia, Uganda, and the United Kingdom). Adopting a developmental and participatory approach, the evaluation process is organised as a Citizen Science initiative itself, with the evaluation team consisting of experts and local citizens. The article demonstrates the benefits and challenges of tailoring Citizen Science evaluation processes to the needs of the project and involved actors, especially when anticipating long-term impacts and institutional or societal change.

Inspired by co-creation methodologies from design thinking, Catharina van den Driesche and Sarah Kerklaan focus in their paper on visual co-analysis models as a specific method and examine its value as a potential instrument for participatory evaluation and inclusion. Since Citizen Science often propagates opening up scientific knowledge production to participants with a wide variety of educational and literacy levels, it requires methodologies that facilitate this participation. Co-creation methodologies might be an effective instrument to bring different knowledge types together and generate constructive exchange. In a case study on technological support for informal caregivers working in healthcare, the authors use visual co-analysis based on affinity diagrams to create a research question together with academic researchers, caregivers, and human resource advisors. They discuss how the method can empower non-academic participants as well as academic researchers in decision making processes.

Addressing a similar gap in the impact evaluation literature in the context of innovation, Katrin Uude, Kerstin Kurzhals and Annika Wesbuer introduce their adaptation of the Payback Framework. In their theoretical paper, they adapt the framework by introducing the perspective of the Service-Dominant logic to allow for a more holistic approach to co-creation and the variety of actors and resources involved. While the article recognises there is no one-size-fits-all model, it emphasises how the inclusion of more dimensions leads to a better understanding of the various types of impact of participation in Citizen Science. The authors point out the need for broader testing of the applicability and usefulness of the approach they have developed. While the framework allows for citizen involvement in the project evaluation process, it does not currently include an assessment of the success of co-creative practices and evaluation factors such as trust and relationships.

In her praxis report, Annett Richter directs the attention to German national monitoring activities that engage volunteer actors to document biodiversity aspects for sustainable agriculture. The author proposes a set of indicators for Citizen Science-based biodiversity monitoring, which includes the evaluation of participation in relation to the scientific and wider project impact. Considering these indicators not only as infrastructures for quality assurance but also as tools for communication about the project and its results with the public as well as policymakers, they are designed to describe complex relationships in a simplified manner. While these indicators were created to evaluate participation in Citizen Science, their development also opened up potential for making the evaluation process itself more participatory. Richter calls for an integrated evaluation mix: including conventional evaluation from "outsiders" as well as participatory evaluation by "insiders". Such a mix would complement the generic demands from programme funders and academia with more insights on the motivations and benefits for research participants.

All papers in this special issue show how diverse approaches to participation in evaluation can be, how different the chosen dimensions and starting points can be, but also how complex the evaluative questions can become as a result. The last article in this issue focuses attention on the potential of collaborative documentation for evaluation. Julieta Arancio, Emilio Velis and Diego Torres report the development and implementation of a community-based data model for the documentation of a global innovation challenge and the further use of its results. In recent years, such challenges have become a new format of innovation for mission-oriented initiatives. The Global Surgical Training Challenge (GSTC) is a competition aiming to make simulation-based surgical training accessible worldwide through low-cost, open-source training modules. The authors use this challenge as a case study to investigate the opening of the innovation process, where all participants were instructed to make their solutions open source and fully reproducible by documenting them on a specific wiki platform. The data model for this platform – used to guide participants in open documentation of their projects – was evaluated collectively for its capacity to enable reusability and open knowledge transfer. In their praxis report, the authors describe their approach to make it available for application in other evaluation procedures in open competitions or collaborative environments, but also discuss challenges regarding questions of motivation and ownership in implementation of such collaborative documentation efforts.

This assembly of articles – some more theoretical and others more practical in nature – is intended to encourage readers to explore participatory methods for the evaluation of Citizen Science, but also other fields of science, social science, and humanities, as well as Social Innovation. The intention is to overcome the blind spot of Citizen Science evaluation: project results and participation should still be evaluated, but the means and formats of this evaluation should be jointly created or at least negotiated with the participants. Central to any participatory evaluation is the initiation of an open, reflexive process for a systematic assessment of activities and results. While participatory evaluation is not applied to all aspects of a project, for reasons laid out above, it can still accompany an entire project course. In any participatory evaluation, it makes sense to focus on some central aspects or activities, or to work participatively with selected, representative actors. We acknowledge that the processes involved are costly in planning and organisation, often require specific training, may despite all benefits represent an additional burden to participants, or are difficult to reconcile with institutional procedures. Evaluation processes should therefore take into account not only expectations about outcomes and benefits, but also expectations about how knowledge is produced. Based on the experience of the assembled authors, we conclude that a mix of methods is likely to emerge, in which the participatory dimensions of evaluation qualitatively complement predetermined indicators and support an agile and adaptive project management. From the various frameworks and field reports, we see many commonalities in the challenges that these types of evaluation seek to address: the high degree of flexibility and the need to tailor evaluation methods; the overburdening of involved actors; the management of the many different interests and expectations; the problem of proving in advance the long-term sustainability of project goals or assessing social or institutional change. But we also see the benefits of treating societal promises according to the participatory credo in an increasingly accountable and auditable world. Citizen Science should always remain a safe experimental space that enables new forms of participation in knowledge production, that drives the transformation of science toward a more open, democratic knowledge culture, and that can create new formats of responsibility and trust for decision-making processes while facing its participants and its resources with the utmost respect. We hope you enjoy reading and welcome feedback and comments (coact@zsi.at).

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PARTICIPATORY EVALUATION PRACTICES IN CITIZEN SOCIAL SCIENCE: INSIGHTS FROM THREE USE CASES

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1. ABSTRACT

In citizen social science, citizens actively engage in research to investigate and solve challenges from their lifeworlds. As these interests are guiding the research process, we suggest employing a co-evaluation approach as a form of participatory evaluation that initiates the conversation on expectations and impact with the diverse actors involved from the onset. In the European funded research project CoAct, global social concerns such as youth employment, mental healthcare and environmental justice are addressed by three local research teams consisting of affected citizen groups, thematic and political stakeholders, and multidisciplinary academic researchers. The teams investigate and implement concrete actions and strategies to tackle these social challenges. In this contribution we reflect on first insights of co-evaluation from the three cases by applying a qualitative content analysis across different content formats, focusing primarily on the specific challenges and outcomes of citizen social science and co-evaluation. While the nature of the social issues at stake and the distinct socio-cultural contexts in which they are embedded clearly mark the boundaries of comparability, overall, a shift in roles and ownership across involved actors is observable. Identifiable intermediate outcomes are e.g. an increase in awareness, knowledge, and skills amongst stakeholders, which are in the long-term expected to increase empowerment, self-determination and the quality of life of the concerned participants, and lead to the implementation of new measures and regulations at policy level. With this work we want to contribute to the canonical development of citizen social science and generate productive feedback for the research process.

2. INTRODUCTION

Citizen science and participatory research processes have gained attention across disciplines in recent years. Academic publications with reference to citizen science have notably increased in the last two decades (Pelacho et al., 2021). According to bibliometric analysis, the dominating disciplines of citizen science belong to the natural sciences, which embrace a wide number of participatory practices, such as nature observations, data collections, classifications and analysis, or biohacking.

Citizen science activities within the social sciences appear less prominently in current scientometric literature, although they are starting to gain traction. Their lower visibility is mainly attributed to two reasons. First, social sciences often work in inter- and multidisciplinary settings and thus their activities may be either labelled as such or hidden behind other fields of science (Pelacho & Sanz, 2021). Second, participatory research practices in social sciences are often not labelled as citizen science, including for example more activist-driven science (Kullenberg & Kasperowski, 2016).

Clearly, social sciences have been highly influential in the current understanding of citizen science as defined by Alan Irwin (1995), who stresses its democratic potential by addressing the needs and concerns of people who develop and enact scientific practice themselves. In social science, participatory practices have a long tradition, e.g. in community-based participatory research (CBPR) or participatory action research (PAR). PAR (Alderson, 2008; Fals-Borda & Rahman, 1991) paved the way for our contemporary understanding of participation in citizen science. It consists of a set of approaches that emphasise the involvement of the research subjects as co-researchers on equal footing in the research process (Whyte, 1990), who act as "joint contributors and investigators" (Given, 2008: 599). Combined with a turn to social epistemology (Fuller, 2012; Harding, 2004) in order to both study and evaluate the social dimensions of knowledge production and innovation, it is possible to focus on the manifold similarities and differences of the epistemic and normative understandings of the world that stakeholders/participants bring into a process.

One of the challenges in citizen social science is to find appropriate ways to deal with the "double hermeneutic" (Giddens, 1987) in a participatory and inclusive way: social phenomena, even before they are professionally analysed by social scientists, are already meaningfully constituted. This raises the question how this exchange between the two (or more) frames of meaning is organised so that interests are considered both from science and society. This concern is particularly pertinent for the research design of citizen social science, where citizens act as co-researchers themselves, and needs to be considered in the assessment of project activities and outcomes. Thus, in citizen social science we are faced with challenges from the lifeworlds of co-researchers, whose frame of reference is not academic and who instead expect changes in their personal lives and socio-economic contexts from their participation in citizen social science endeavours (Albert et al., 2021).

In this paper we reflect on the first insights of evaluating three cases of citizen social science that are part of the ongoing European funded project CoAct. We elaborate our approach of co-evaluation facing challenges of deploying a participatory evaluation design during a global pandemic.

3. PARTICIPATORY EVALUATION

Participatory research requires a participatory view on evaluation. Approaches towards evaluation in research activities tend to be understood as a systematic assessment of the operation and/or the outcomes of an activity or program, against a set of explicit or implicit standards and criteria (Weiss, 1998). While such approaches tend to be pre-structured and top-down, they benefit from being complemented with a more bottom-up and participatory view, especially when dealing with social issues at the core of the scientific question. Since participatory paradigms have become central to orchestrating the (co-)production of knowledge aligned with different social needs, the question remains: How useful is this generated knowledge? How are co-production, co-creation and participation practices valued by the participants and other involved stakeholders? Valuation in this regard subsumes "any social practice where the value or values of something is established, assessed, negotiated, provoked, maintained, constructed and/or contested" (Doganova et al., 2014: 87) and can be regarded as critical sites of social (trans-)formation (Lamont, 2012). Following this, we consider evaluation in citizen science as such critical site of social transformation. It provides the time and space to reflect on results and to negotiate the processes for further action, especially in the context of evolving interests and flexible project management (Shirk et al., 2012). Furthermore, evaluation is needed to assess the "promise to the public" (Eleta et al., 2019) that is inherent in any citizen social science project, as well as to balance stakeholder expectations.

In line with Cousins & Whitmore (1998), Brisolara (1998) suggests differentiating along a continuum of types of participatory evaluation, from status-quo-oriented evaluation to more action-oriented, ideological, transformative evaluation. In our understanding, citizen social science projects require more of the latter type of evaluation. These projects typically include non-traditional stakeholders, such as civil society organisations, schools, and individuals, and might even be initiated or led by private initiatives without any formal affiliation. The main interests and motivations of these stakeholders are action-oriented such as social change or learning and capacity building. Thus, objectives, methods, and actors involved in such projects are as diverse as the topics and social concerns covered. This calls for tailored forms of evaluation that consider the expectations, benefits and challenges raised and experienced by all involved actors, as well as more general social impacts. The joint definition of expected outcomes – by all actors – and the selection of methods on how to provide evidence for these constitutes a participatory approach to evaluation, which Mayer et al. (2020) labelled *co-evaluation*. It is defined as a process that involves all relevant actors in a project in an iterative evaluation practice and adapts methods of participatory action research for evaluation purposes. Project goals and objectives, understandings of success, challenges, and unintended effects are collectively discussed and documented at the beginning of a project and regularly re-visited during the research design and execution, ideally beyond the project's end. Assessment and intended impacts hence become transparent entities in the project design.

Co-evaluation clearly takes a transformative stance, as it includes co-creation methods that aim not only at learning about a situation but also at overcoming hindrances and finding solutions to problems, such as how to measure the success of a research project in terms of stakeholder benefits. The combination of experiential learning (e.g. about power, difference, inequality) and critical reflection of socio-political and cultural relations as well as assumptions deeply embedded in processes of social change, provides a robust basis for inclusive evaluation procedures. Furthermore, in transdisciplinary research it is considered crucial that co-creation processes require coordination, expectation management, and attention to the community building processes, in other words "some a priori conceptualization of which internal and external people need to work together, what they want to do together, and what value they will create as a new community" (Gouillart, 2012, p. 2). In such processes, different normative regimes need to be aligned or configured so that benefits for all participants are considered in a balanced way. Evaluation procedures therefore must consider not only the expectations towards the results and benefits, but also the expectations towards the ways knowledge is produced, adding another layer of complexity.

A comprehensive approach to citizen science evaluation and impact assessment has been provided by Kieslinger et al. (2018). Their framework (Fig.1) suggests indicators for three dimensions of participatory scientific processes: 1) scientific aspects, 2) participants, and 3) socio-ecological/economic systems. For each of these dimensions the framework suggests process-based and outcome-based evaluations. "Process & feasibility" collects formative input for an adaptive project design and management, while "outcome & impact" brings evidence of a project's benefits to its participants and the contexts in which the project is embedded. It also shows how much an intervention's impact contributes to the project's expected and possibly unintended goals.

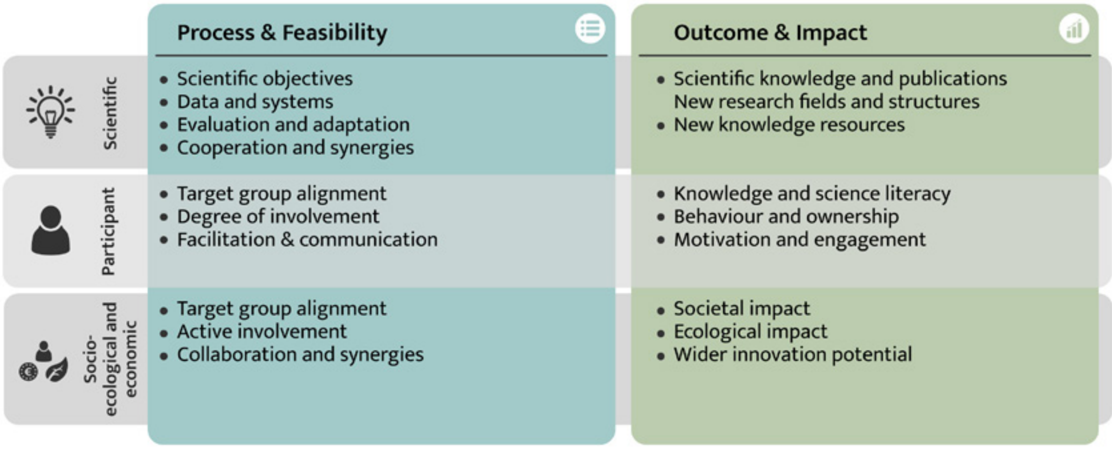

Figure 1: Citizen Science Evaluation Framework by Kieslinger et al., 2018

According to the authors, some of whom are co-authors here, evaluation should be understood as a learning process that supports self-reflection and adaptive management, while on the other hand helping to understand which effects citizen science initiatives have on science, involved citizens and socio-ecological systems. This understanding of evaluation as a learning process aligns well with the understanding of "participation in the making" (Chilvers et al., 2016) and issues at stake in citizen social science. Thus, the above framework fits well for our analytical purpose and serves as a first structure for the qualitative analysis of the three citizen social science cases presented in the following section. We will then elaborate further on the methodological approach in Section 5.

4. CONTEXTUAL SETTING: THREE CASES OF CITIZEN SOCIAL SCIENCE

The work presented is part of the European funded collaborative research project CoAct. The overarching objective of the project is to advance citizen social science as a transdisciplinary research approach and enhance its methodological repertoire. Our data is based on three concrete case actions which are carried out under the umbrella of CoAct:

In Austria, young people mainly aged 15-18 who are not in employment, education, or training, critically examine social policy measures currently in place to support young people out of school enter the first job market. The research team further includes educators, social welfare agencies, and policymakers. The aim is to restructure these measures to better address the needs of the young people mandated to take part in them. They are involved as co-researchers, gather interests and needs of their peers, and work on the conceptualisation and improvement of the measures. Insights from the research process are disseminated and discussed with representatives of welfare agencies and social policy makers, aiming for the implementation of the new measures in practice.

In Spain, the involved citizen community is constituted by adults with an experience of mental disorders and their families, living mostly in Catalonia. They form a research team with representatives from care institutions and scientists to co-define measures for strengthening social support networks of persons with mental disorders. As scientific research on the role of the family and other social support networks in the recovery process is still scarce and lacking evidence, the pilot seeks to make visible the broad community of people and institutions involved in the field of mental health, and to place at the centre of the research the voices and knowledge of individuals with an experience of mental health and their families.

The third case is implemented in Argentina, where social activists, residents and multidisciplinary researchers co-create a community platform to counteract socio-environmental risks in the highly polluted residential area of the Matanza Riachuelo basin in Buenos Aires Province. The citizen community is composed of inhabitants and workers in the basin who as socially disadvantaged citizens groups carry the main burden of pollution. The aim of the research process is to identify socio-environmental problems and social practices to tackle them using citizen social science tools. As an environmental justice initiative, actions are framed in the context of official sanitation policy. The case should help to identify divergent patterns of desired and actual policy solutions and processes, and thereby advance clean-up policies and improve the situation of people regarding their health and rights. Insights from the research process are disseminated and jointly discussed with local policy agents, aiming for the implementation of the proposed measures in practice.

In addition, each case involved wider stakeholder groups, including political decision makers, in the form of a knowledge coalition (KC), which facilitated access to and provided expertise about the field. As such, a KC allows for affected citizen groups to address their concerns directly to relevant stakeholder organisations, experts and decision makers and develop sustainable solutions together.

Participation was designed to allow for co-researchers to involve themselves according to their preferences with regards to formats, continuity, intensity, and thematic focus. KC member participation was managed by the core research team in each case and focused on dedicated meetings. As such, it is difficult to clearly outline the number of participants, although by the end of the project's second year we counted about 260 engaged individuals in total.

5. RESEARCH DESIGN, DATA, AND METHODOLOGY

Each of the three cases implemented participative evaluation activities, guided by a team of researchers who coordinate the overall evaluation and impact assessment strategy of the CoAct project. This evaluation team – consisting of the four co-authors of this paper – co-created and applied the evaluation approach together with the local research teams – both academic and lay co-researchers. The cases were assessed along predefined overall project goals, as well as according to case-specific criteria which were defined and adapted during the project through co-evaluation. In the remainder of this paper, we focus on these co-evaluation activities. During the first two project years the interactions with co-researcher and the knowledge coalitions were mostly taking place in digitally mediated settings due to the COVID-19 pandemic. Activities started with an exploration of the field and establishing first working relationships. Then, actors co-designed the research and conducted research activities related to the topic under investigation. This phase was implemented iteratively and tied closely to co-evaluation activities, which were an integral part of the process. Thus, all participants were involved in evaluation activities to a certain degree, with certain challenges encountered along the way (see Chapter 6). The next phase of data analysis and interpretation of results is still ongoing. Thus, the reflection on the participatory evaluation presented here is mostly of a formative nature. Evaluation activities included initial explorations of expectations, motivations, or goals and joint reflection exercises and self-assessment during the co-design phase of the research (Fig. 2).

The evaluation activities performed during 2020 and 2021 serve as the main data sources for this analysis. Our framework (see Fig. 1 above) allows for a symmetrical, comparative analysis across diverse types of stakeholders and engagement. To understand "participation in the making" (Chilvers et al. 2016) and issues at stake in citizen social science, we followed the positions and valuations of actors over time with a range of methods: interviews, participatory observations, group reflection exercises, self-reflection surveys, etc. Triangulation then involved combining those different types of data and data collection methods to answer the

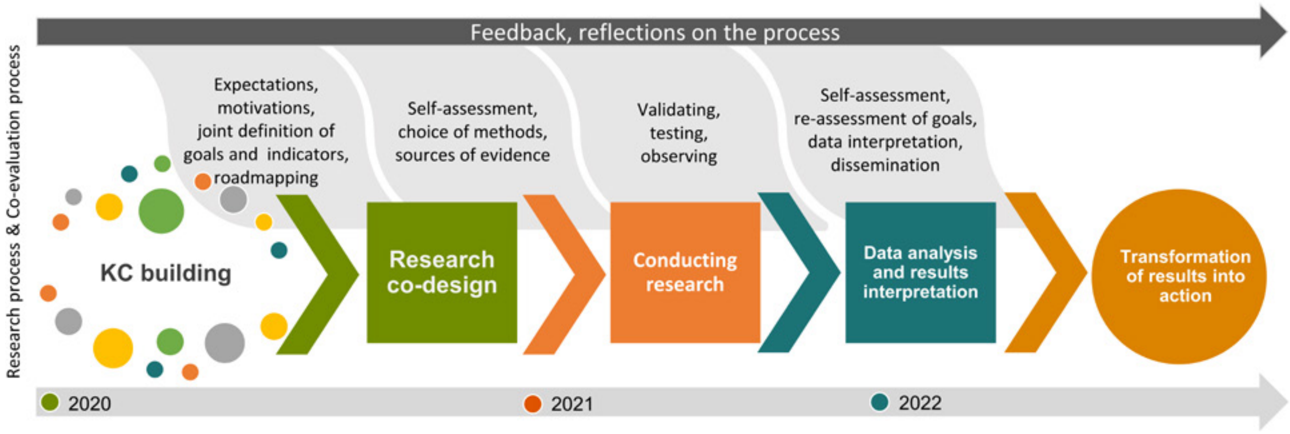

Figure 2: Overall research and evaluation process of CoAct R&I Actions

research questions, namely how can we implement participatory evaluation in citizen social science projects, what are important elements and commonalities in the process, where are the limitations and what are general characteristics of citizen social science?

Our multilingual (English, German, Spanish and Catalan) data corpus consists of about 200 documents collected over 20 months. The documents range from screenshots of drawings, virtual post-it walls, interviews, photographs, transcripts of group discussions, surveys, digital message boards, to observational notes from researchers. They were partially provided by the research partners leading the different case actions and partly collected by the coordinating evaluation team. Direct access to the various actors of the three cases has been limited for the evaluation team due to language barriers, a lack of resources and the complex conditions brought forward by the pandemic. Most of the data had been anonymised by the local research team, which added a layer of complexity for the overall analysis by the evaluation team. An overview of the various types of data sources analysed is provided in Table 1.

Spain	Austria	Argentina
• 1 COVID-19 self-reflection (A) • 2 Self-assessments (A, Co) • Co-evaluation roadmap (A) • Researchers notes (A) • 1 Expectations padlet (KC) • 1 Expectations follow-up survey (KC) • 1 Expectation reflection (Co) • Follow-up feedback (Co) • 1 FrenaLaCurva Survey (O)	• 1 COVID-19 self-reflection (A) • 1 Self-assessment (A) • Co-evaluation roadmap (A) • Researchers notes (A) • Reflection meeting notes (A) • 1 Expectations padlet (KC) • Minutes and summaries of 7 meetings (KC) • 1 Expectations follow-up survey (KC) • 10 interviews (KC) • Project week feedback (Co) • Project week outputs (Co) • 16 Actionbound inputs (Co)	• 1 COVID-19 self-reflection (A) • 1 Self-assessment (A) • Co-evaluation roadmap (A) • 1 Expectations padlet KC) • 2 Documents on expectations (KC) • 15 Interviews (KC) • 2 Interviews (Co)

Table 1: Evaluation Data Sources from the CoAct R&I Actions (A=Academic Research Team, KC= Knowledge Coalition, Co=Co-Researcher, O=Other)

Each case started with a co-evaluation roadmap that has been continuously updated during the project to allow for joint planning. Shortly after the onset of the pandemic, the evaluation team guided all cases in a COVID-19 self-reflection to support their restructuring where necessary and identify the impact of the pandemic on the topics, processes, inputs, and outputs of the cases, discussing common challenges and possible solutions. All stakeholders were engaged in the definition of expectations and goals towards the project. All three case teams (lead partners of each case) undertook a self-assessment group survey midway through their case implementation, realised as a conversation, and guided by the evaluation team. Additional data sources for evaluation specific to each case include research notes and diaries by academic researchers, various expert interviews, and interviews with members of the knowledge coalition, reflections with co-researchers and participant surveys, with some employed methodologies generating a larger data corpus than others.

For our data analysis, we mainly used a hermeneutic approach to qualitative content analysis, a method that helps to order and structure manifest and latent content in and across transcripts and text-based data collections. We are referring mainly to Mayring (2014, 2019), who has co-developed the method since the early 1980s in the tradition of objective hermeneutics and grounded theory. At the centre of the analytical process is the systematic coding of text material. Our focus of the coding was on a qualitative interpretation of the data, even though quantifying analysis can be applied in a supportive manner, e.g. for visualisations.

In the coding process, the evaluation team assigned categories to the data material. The work was done deductively alongside the category system developed in our framework (see Fig.1 above) and inductively as the categories also emerged from the data material. Codes were described in memos to permit a constant, observable, and intersubjectively understandable procedure and let the analysis be substantiated by the material. In cycles of communicative validation, the involved researchers compared coding and codes documents, over time and by discursive agreement harmonising the individual inductive coding into a coding scheme adapted to all material in the corpus. Due to constraints on time and collaboration brought on by the pandemic, this analysis was undertaken by the evaluation team alone, although the findings were shared with the local case teams for additional input and reflection. In the following, particularly unifying and diverging aspects of the cases identified in the analysis are presented.

The researchers involved in the analysis and main authors of this manuscript – the evaluation team – are female academics at the Centre for Social Innovation in Austria, bringing in interdisciplinary perspectives, with an academic background spanning the disciplines of sociology, pedagogy, and economy. They remotely interacted with the local research teams, guiding them on how to implement the co-evaluation approach, attending relevant meetings and conducting interviews. Partners were instructed to follow a basic set of co-evaluation principles, such as a commitment to openness and reflexivity, flexibility, documentation, and transparency. For all participating actors, informed consent information and forms were provided in the local languages and administered by the local case partners (CoAct Partners, 2021).

6. ANALYSIS

Taking the original framework for evaluation and impact assessment in citizen science (Fig.1) as the starting point offered valuable insights into the three dimensions of 1) science, 2) participants and 3) socio-ecological/economic systems. While the original structure of the evaluation framework was very helpful in approaching the data, the combination of inductive and deductive coding led to a slightly different structure for grouping the insights gained so far. Thus, the key aspects derived from the analysis are presented along 1) the scientific process, 2) the engaged actors and their roles, and 3) the expected and already achieved impact, followed by 4) a general reflection on challenges and limitations of co-evaluation.

SCIENTIFIC PROCESS

Citizen social science puts **societal problems in focus** and aims to offer detailed insights from and with the affected actors' point of view, contributing to potential strategies to overcome these issues. The data contained many instantiations of how strongly the case-specific objectives are rooted in the daily lives of the co-researchers, addressing personal concerns or societal disadvantages. Clearly, the specific research questions are shaped by the social issues at stake. More abstract and theoretical **scientific objectives**, such as the methodological contributions to citizen social science, are less visible in communications with co-researchers and their motivations than their specific concerns. This focus on social concerns resulted in a less clear understanding of the scientific nature of the actions. Across the cases, the core research teams confirm that they had difficulties in clearly communicating the scientific goals next to the specific societal issues, which however did not seem to concern the engaged actors. This is an indication that in citizen social science, a distinction between social and scientific goals might not be useful or needed for implementing a transdisciplinary approach. Similarly, it might not be necessary for all actors to share the same goals, but rather to agree on the plurality of aims envisioned by the different actors in the process.

When looking at aspects that shape **successful engagement** of the different stakeholders, the data showed considerable variety across the cases. **COVID-19** restrictions have been a major challenge, as they entailed a mandate to conduct physical activities with less participants, and a more general move from physical to digital engagement options. Digital engagement, however, is very much dependent on access to technology, which makes engaging certain populations much harder, while also limiting the available tools to be employed. This was tangible in all cases, but especially in Argentina, where poverty is an immediate problem for the citizen community. For any sort of active engagement, the analysis reveals the importance of creating an atmosphere of **trust**, which is especially important when participants share difficult personal experiences and are affected by pandemic restrictions. Also, showing **empathy** for individuals and their personal contexts strongly influences the engagement process. In addition, co-researchers appreciated the recognition of their expert knowledge, their abilities, and their different perspectives. Recognition of the power differentials between the actors has been perceived beneficial for the process in terms of the explicit acknowledgement of the complementary skills in the team, e.g. presentation skills of co-researcher, or the delegation of tasks like moderation to external facilitators.

The analysis showed that the cooperation with non-governmental (NGOs) and civil society organisations (CSOs) was highly beneficial and a strong success factor for the engagement process. These organisations are often rooted in the communities and play an important role in the recruitment of the participants and the reflection and dissemination of research results with a wider stakeholder group. While cooperation activities of local research teams were largely problem-focused and scientific collaborations less pursued, communication and outreach are expected to intensify in more advanced project phases when more tangible outputs are available, to allow for a sustainable exploitation of project activities. A relevant finding for the scientific process implementation is also the support and commitment towards **open science practices**. Actors across the cases stress the importance of sharing data and results, such as environmental observations or aggregated information of support networks in mental health, as openly as possible, while protecting privacy of personal data. Especially when the development of digital tools is involved, the importance of simple and easy to use interfaces (e.g. data collection tools for mobile phones with low bandwidth or for offline use) and data sharing beyond the core research group and beneficiaries is emphasised. This goes hand in hand with high expectations in terms of impact for more visibility and community building, which will be discussed further on.

ACTORS AND THEIR ROLES

In participatory research and evaluation, participation means the active involvement of participants. In the CoAct cases three groups of actors – professional researchers, co-researchers, and knowledge coalition members – inhabit the participatory research process. The degree of engagement of these actors varies greatly and is closely connected to the identification with the social issues at stake and to feelings of **ownership**, i.e. taking initiative and responsibility for a process. The analysis shows that motivation to participate is closely entwined with the identification with the social problem. In the case of co-researchers, engagement is also strongly tied to the available engagement options as well as the temporalities of their participation. The different degrees and facets of ownership are e.g. illustrated by contrasting the Austrian case, where co-researcher ownership is highly situative and limited to the short instances of direct engagement, with the Spanish case, where co-researchers are engaged along the whole research process. These longer engaged actors show not just ownership for the topic but even take on an active part in shaping the research process on a higher level. Ownership has thus been encountered across most engaged actors, but it is clearly limited by the engagement options they are offered. Regarding motivations and expectations, the data confirm an overall strong link to the problem situation, which is either relevant to their personal life, work, or both.

Professional researchers are important actors and the main drivers of the whole process across the three cases, often working closely with a CSO or NGO, to design the participatory activities and oversee the entire research process. As the initiators of the project, they are responsible for administering project funds, which causes a built-in structural power differential that is hard to overcome. Simultaneously, the data shows some **shifts in the roles** the professional researchers take on. Citizen social science requires specific skills and competencies to facilitate the participatory process, to communicate in adequate ways with the target groups, and to manage expectations. While some researchers take on these additional roles of facilitator and communicator, others decide to invite new actors to the process to take on these roles. It can unburden the academic researchers from acting both as joint researchers on equal terms with the co-researchers while also taking on the responsibility of facilitating the process on a meta-level. Managing the different expectations and interests in a "disinterested" way brings about a potential role conflict for academic researchers. External facilitators may also address hierarchical structures more directly and help establish equal power relations. In the context of CoAct, the professional researchers' role is complicated by the fact that their main aim is to further develop citizen social science and its methodologies, next to working solution oriented. Thus, they need to manage different and sometimes contradictory responsibilities as part of the "triple hermeneutic" of citizen social science[1].

In CoAct shifting roles across all participating actors can be observed. While starting from three rather clearly defined groups of actors, the roles are changing for many of these actors during the participation process as new relationships emerge. In the case of Austria and Argentina knowledge coalition members increased their participation and ownership; they gradually engaged more and more in the research process and might even become a new category of co-researcher. In Spain, a strong community is emerging from the interaction of the co-researchers, who also show a growing level of ownership for the whole research process and take on ever more tasks and responsibilities. Some of the co-researchers even become core researchers as they take ownership of the research process, including research data analysis or participating in academic dissemination activities. This process seems to be at least partly based on an emergent, potentially sustainable community in the making that we observe from the Spanish case.

SOCIO-POLITICAL DIMENSION

As the three case actions are still in progress, the collected data provides more evidence about the process implementation than of concrete impact. Overall, strong expectations emerged to achieve societal impact, in terms of empowerment and social change, by increasing visibility and awareness, fostering capacity building and inclusion, personal gains for co-researcher, and creating communities of interest and networks. However, the degree of empowerment that can possibly be achieved in these specific actions varies greatly and is dependent e.g. on the degree, temporalities, and structural possibilities of involvement of the various stakeholders, their motivation for participation, and the organisational options provided by the involved NGOs and other actors for follow-up activities.

Impact levels vary across the cases. While in the Argentina case on environmental justice the community gains are clearly in focus (community level), the data from the Barcelona case on mental health support networks holds more reference to the personal gains and a destigmatisation of the affected population (individual level). Similarly, in the Austrian case on youth employment, references towards personal gains dominate, although there is also some reference to sustainable institutional change to positively affect actors on all levels. Interestingly, in this case the improvements for the citizen community of young people are tied closely to improvements in the working conditions of trainers and social workers, who make up a large part of the knowledge coalition.

Personal impacts may entail learning and, more generally speaking, the educational goals that project activities pursue. There are clear indications in all cases that increased **knowledge and skills** on the side of all actors are envisioned, and the analysis reveals some evidence that learning has taken place on an individual level. As some of the topics of the cases touch on highly personal and emotional subject matters, a previously unforeseen personal impact was described both in Spain and Austria as the "**therapeutic effect**" that the community interactions within project activities had on some participants, brought forth by an open and sympathetic exchange on personal struggles and experiences.

1 Referring to Giddens' (1987, p.30) "double hermeneutic", a "triple hermeneutic" stance illustrates the further layers of interpretation added by reflexive evaluative practices to the meaningful worlds of co-researchers or research participants.

Finally, awareness-raising beyond the cases, for the specific topics as well as for the method of citizen social science, has been identified as an important impact that actors aim to achieve. This is closely connected to the wish of establishing connections and networks with other organisations that deal with similar issues beyond national borders.

CHALLENGES AND LIMITATIONS OF CO-EVALUATION

Many of the aspects identified during the analysis are familiar from participatory social research and citizen science (Cousins & Whitmore, 1998; Wehn et al., 2021). The difference here, however, is that these aspects can now be further developed collaboratively as evaluation criteria in the project, and that the findings from the evaluative monitoring are regularly fed back into the research process. Thus, the co-evaluation approach aims to qualitatively enrich the catalogue of evaluation criteria, which are usually pre-defined and established along the project objectives before the project start. The participatory-interventionist approach of co-evaluation aims to contribute to achieving the project goals and initiating social change.

In CoAct, the evaluation team has seen both very promising and challenging aspects of implementing co-evaluation principles. Promising observations include the establishing of trustful, empathetic relationships across actors and the flexibility in adapting evaluation methods to the needs of engaged stakeholders as well as to the challenges caused by the COVID-19 pandemic. However, participants have also experienced some difficulties with co-evaluation, although to different degrees and for different reasons. In citizen social science the social issues are dominating over scientific goals, which makes it sometimes difficult to assess the scientific objectives. This can present a challenge when evaluation must respond to pre-defined scientific criteria defined by research funders, such as co-published high impact publications. Resources for evaluation are limited and co-evaluation, which is a flexible learning process, often requires more engagement than originally foreseen, especially during a pandemic. The three cases have not always been able to implement the "co" in co-evaluation to the extent planned. As most activities in CoAct take place in virtual settings, there has been a need to integrate co-evaluation activities into the online interactions with the project stakeholders. Since online sessions should be very structured and take less time than physical encounters, trust is less easily established and thus, the evaluation team is sometimes – quite rightly – deliberately excluded to simplify the activities for the co-researchers. Not all partners in CoAct can share the same details with the evaluation team due to privacy protection, and the level of access to the various project actors differs widely across the cases, roles, and levels of engagement. Fully anonymised data make it hard or impossible to follow up for further co-evaluation activities. To organise the evaluation, many pre- and post-evaluation meetings are needed. Given the additional challenge of language barriers, it is important for all to rely on well-established collaboration structures and continuous reflections and adaptations between the core-research teams and the evaluation team.

Overall, the **evaluation** concepts and how to implement them in a participatory process were not always clear for all engaged actors, including the professional researchers. The local teams were struggling with defining clear scientific project evaluation strategies, which might be due to the fact that they are driven by social issues and less by scientific objectives. An even greater challenges was the implementation of the concept of co-evaluation. Although the defined principles of co-evaluation are widely appreciated, the difficulties arise mostly in how to apply them in concrete settings. It requires a very flexible and responsive process and a strong commitment from the (co-)researchers, not only for the research process but specifically for the evaluation process. This was further exacerbated by the externality of the evaluation team, which had to be actively included in case activities throughout planning and implementation, making for sometimes muddied responsibilities. While evaluation aims were sometimes hard to communicate to and elicit from the various core actors, it was also challenging to disentangle "evaluating" from "being evaluated".

In summary, the participatory approach to evaluation, adapting the original framework (Fig.1), further defined and clarified the following (selected) evaluation criteria and challenges:

	Process and Feasibility	Outcome and Impact	Challenges
Scientific Process	• Participant commitment to scientific objectives • Engagement options in times of a global pandemic • Transdisciplinary cooperation	• Knowledge production and sharing (incl. publications, conferences, etc.)	• Blurred lines of different objectives • Science offers methods more than topics • Scientific questions need to be secondary to social issues
Actors and their roles	• Ownership of problem and process • Flexible roles and functions of actors in the research process	• Ownership of results and dissemination • Self-experience in different roles • Experience of personal effects	• Resources, temporalities and situated participation • Institutional role pressures • Dynamics and complexity of the process through shifting roles • Feelings of "being evaluated" • Interest and expectation management
Socio-political	• Capacity building and inclusion	• Empowerment by increasing visibility and awareness, also for policy makers • Community building and networking	• Connecting to policy makers • Evaluation of diverse communication and visibility activities • Translatory capacity

Table 2: Co-evaluation criteria of citizen social science case actions

These criteria influence the further co-evaluation of the CoAct project, as it already provides indications about aspects that appear to be particularly important for the project. At the time of writing, evaluation has been mainly formative/process-based, which allows for flexibility and adaptation of the process to highly fluid and often challenging context conditions.

7. CONCLUSIONS AND OUTLOOK

Citizen social sciences provides the opportunity to study and evaluate the social dimensions of knowledge production, focusing on different understandings that stakeholders bring to the process – and deducing actions that address the social problems under investigation, bringing some concrete benefits to the lives of participants. The challenge in this process is to organise and understand the different meanings and interests of scientists, co-researchers and other relevant stakeholders and manage expectations of participants who bring their non-academic frames of understanding into a scientific process while expecting concrete and positive changes to their lifeworlds. This challenge becomes even more complex when the collaborative processes are shifted primarily online in response to a pandemic. To embrace the dynamics of this process considerable flexibility and adaptation is needed when setting up and implementing citizen social science initiatives.

In this specific context the establishment of trustful relationships is key to openly share and analyse the knowledge and experiences related to each social problem. In turn, professional scientists are challenged with acquiring new skills sets that include designing methods for collaboration in digital environments (often among stakeholder groups that have reduced access to new technological devices) and empathically moderating/facilitating these online collaboration processes when sensitive topics like mental health and environmental justice are discussed. Thus, scientists must switch roles between research and facilitation, between technology design and community management, or create new roles and onboard them, such as facilitators, who help to moderate or document the research process. Similarly, co-researchers take on new responsibilities: not only bringing in the experiences and meanings of their lifeworlds but taking an even more active part in the knowledge production by stepping into the worlds of professional scientists and building new communities. Knowledge coalition members on their part are strongly involved, to the point of acting as co-researchers. This dynamic research process contributes to highly valuable knowledge gains (both on the topic under investigation and the scientific process) of all those directly involved, while for some participants first improvements of their lives are noted through the "therapeutic effect" of these interactions. The flexibility in taking up non-traditional roles not only enriches the collaborative research at hand but drives valuation practices as defined by Doganova et al. (2014) and confirms the reconfiguration of roles and responsibilities in citizen social science (Albert, 2021). In the complexity of a citizen social science project, it is thus particularly important to observe the flexibility of the roles and functions of both researchers and co-researchers.

Co-evaluation is expected to trigger a collaborative discussion of goals, understandings of success, and challenges of citizen social science activities. Even though not all the original co-evaluation plans could be implemented in the CoAct project, it can be clearly determined that the participatory evaluation approach has been worthwhile. It supports formulating and tending to expectations and their evolution from the beginning of the project, and thus also observing the important contributions of such projects to social transformation. In many reflexive moments of the evaluation process participants discuss or negotiate the value of their participation and researchers elaborate on their experiences in the project. The co-evaluation process also triggers the continuous control of the research process and collaborative reflection on how to overcome project hindrances (Shirk et al., 2012), deepening the understanding of how knowledge is created in different citizen social science cases.

Evidence shows that in addition to the already difficult handling of the question of proximity and distance between researchers and co-researchers, a meta-level of reflection has been added, which requires great care for evaluation activities not to get lost in a kind of "triple hermeneutics" by creating too many meta-layers of reflection and interpretation. Many of the participants are working with social science and co-design for the first time, so evaluation – if done too intensively – may cause confusion and distress. This is true both for the collaboration with co-researchers and professional researchers. To this end, it will be primarily a matter of further developing appropriate and preferably unintrusive methods that also work in online settings that are even better integrated into project activities. While there are clear indications of participants taking ownership of the research, a similar shift in ownership of the evaluation process is not observable yet. This raises the question of how to create ownership of the evaluation process across all actors, or whether to continue a separation of respondents and researcher roles in citizen social science as suggested by Richardson (2014).

With the end of the project approaching, the evaluation focus shifts from a formative/process-based approach towards a summative/outcome-based one. Turning to the project results may then shed light on further aspects, such as the question of "digital literacy", the handling of data and technologies in co-design and use, the formation of new networks or building of communities, the adoption and further development of the results by the communities and stakeholders involved, but also the socio-political innovations that could be stimulated by the project as well as new methodological insights into citizen social science practices. Based on the CoAct experiences and input from participatory research experts we will publish a Whitepaper on co-evaluation principles at the end of 2022 with concrete recommendations for implementation.

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ACADEMIC MANUSCRIPT

REFLECTING ON DEEPENING PARTICIPATION IN RECRUITMENT AND EVALUATION IN CITIZEN SCIENCE - LESSONS FROM THE WECOUNT PROJECT

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ABSTRACT

This paper focuses on an urban mobility citizen science project in which citizens participated in several ways, from technical development to engagement and evaluation. Drawing on asset-based community development, the WeCount project aimed to empower citizens to take a leading role in the production of data, evidence, and knowledge around mobility in their neighbourhoods. WeCount engaged with thousands of citizens in five European case studies, who were involved in co-designing the data platform, collecting/analysing the data, and lobbying for change. In WeCount, each participant mounted a low-cost, automated, road traffic counting sensor (a Telraam) to a window in their house that faced a road. The Telraam sensor counts the number and speed of cars, large vehicles, cyclists, and pedestrians. Given its efforts to distribute resources and share knowledge for bottom-up sustainable development, WeCount is representative of the shift towards greater participation and self-reflection in the design, delivery, and evaluation of citizen science. Future iterations of similar citizen science projects, as suggested by citizens, would benefit from more training in how to be an activist, more opportunities to get involved in each stage of the project and more training on how to understand the data to ensure the future of urban transport and mobility puts citizens at the centre of decision-making.

INTRODUCTION

CITIZEN SCIENCE: A SPECTRUM OF INVOLVEMENT

Humans have always sought to understand and explain the world around them but the philosophy and practice of citizen science (by contrast with professional science) was not defined until the 1990s (Irwin, 1995; Bonney, 1996). Despite the twenty-five years since those first definitions, there still remain arguments over exactly what Citizen Science is. Unsurprisingly, since its formalisation as a concept in the 1990s (Strasser et al., 2019) its definition has remained ambiguous. Table 1 summarises a typology of the features of citizen science along two spectra: level of participation and ownership of knowledge and data. Given the differences of description, it's unsurprising that new concepts, such as community science, crowd science, and volunteer monitoring, have been introduced to attempt to define the phenomenon more clearly (Strasser et al., 2019).

However, if, as we do in this paper, one regards citizen science as a spectrum, one can locate a range of activities along it, depending on the level of citizens' involvement and the locus of knowledge. Along this spectrum, citizens could be involved in any or every step of research, from defining problems to developing projects, collecting data, working with technology, interpreting datasets, presenting findings, offering solutions/interventions, sharing results and evaluating processes – this is often called engaged research (Grand et al., 2015).

Until recently, most research involving citizen science used citizens as contributors (e.g., data gatherers) to researcher-led processes rather than as co-creators, and projects were researcher- rather than community-led (SCU, 2013). However, a recent political turn in citizen science, driven in part by the need to accelerate sustainability transitions, means that projects are moving from a "productivity view" to a "democratic view" centred on citizen empowerment and policy change for adaptive resource management and governance (Sauermann et al., 2020).

Engagement *with* citizens with the intent to develop co-created and co-produced citizen science, requires a shift of power away from scientific institutions and towards community partners and citizens. Using the example of the WeCount project, this paper will explore how citizen science projects can develop community participation in citizen science and how such projects can be collaboratively evaluated.

Table 1 - Typology of features of citizen science projects, adapted from Bäckstrand, 2003; Conrad and Hilchey, 2011; Dibner et al., 2018; Haklay, 2013; Shirk et al., 2012; Cooper and Lewenstein, 2016.

	Contributory crowdsourcing	Distributed intelligence	Participatory science	Empowering, democratic approaches
Participation	Citizens as sensors (observers) and data providers, submitting data to an online platform.	Citizens as basic interpreters. Sometimes known as 'volunteered thinking', sharing information and responding quickly.	Citizens play an active role in decision making.	Collaborative science – problem definition, data collection/ monitoring, analysis and action. Can include the co-design of regulatory regimes together with marginalised communities.
Step of the scientific process	Data collection	Data analysis	Some or all	Every step
Knowledge distribution	Scientist-led. Data collector for scientists, with predefined questions or long-term monitoring goals for 'amateurs.	Citizen as data interpreter/ collaborator.	Community-scientist partnerships to document change through the collection of local and traditional ecological knowledge.	Citizen-led. Citizen as scientist, collecting and analysing data on community-generated questions with the assistance of professionals. Seen as lay knowledge holders.
Category	For the people	With the people	With the people	By the people
Examples	E.g., E-bird (NASEM, 2018), SETI (seti.org) and Smart Citizens (Capdevila and Zarlenga, 2015).	E.g., for conservation (e.g., iNaturalist), science broadly (e.g., Zooniverse) or for disaster risk reduction (e.g., Kankanamge et al., 2019).	E-participation (e.g., Pina et al. 2017) and adaptive governance e.g., ClairCity (Fogg-Rogers et al., 2020).	E.g., radiation post-Fukushima (Kenens et al., 2020), air quality (Griswold et al. 2020); or citizen-generated topics (Cohen et al., 2017).

CITIZEN ENGAGEMENT IN SUSTAINABILITY TRANSITIONS

The need for citizen empowerment and policy change is well exemplified by citizen science projects focused on urban mobility, which seek democratic engagement to generate changes in behaviour. Citizens readily relate to issues around travel (Wibeck, 2014), such as the link between transport and emissions, while being less aware of the ways in which they can act not only to change their behaviour but also to influence policy. Therefore, mobility projects offer the opportunity to discuss climate change action and efforts towards reaching net zero carbon emissions.

Laggan et al. (2021) have documented the emergence of urban mobility citizen science projects that relinquish power to communities and support them to take action. Nevertheless, they note that most urban mobility citizen science projects remain focused on contributory participation. Behavioural and policy change requires an asset-based approach that can build on the strengths and potential of community members to bring about sustainable development (Kretzmann and McKnight, 1993). Asset-based community development – citizen-led, relationship-oriented, asset-based, place-based and inclusion-focused (Russel, 2021a) – has been shown to lead to effective, innovative and tailored solutions that better fulfil the needs of diverse communities, from responses to the COVID-19 pandemic (Russel, 2021b) to wellbeing promotion in schools (Forrester et al., 2020) and resilience to climate change (Hossain and Rahman, 2021). However, evaluations of these projects, from citizens' experience, determinations of the extent to which power and resources have shifted into citizens' hands and the extent to which behaviour and policy have changed are either reported inconsistently or have not been published in peer review (Laggan et al., 2021).

EVALUATING CITIZEN SCIENCE PROJECTS

Citizen science projects are evaluated for several reasons: to help justify the next proposal, to assess impact, to build an understanding of the strengths and weaknesses of and lessons learnt from earlier projects, and to help promote or advertise (Wehn et al., 2021). As evaluations tend to focus on just one or two reasons, this means only certain aspects of a project, such as audience reach, learning outcomes or environmental or policy impact, are evaluated and the evaluations of different aspects are rarely consolidated (Wehn et al., 2021).

Evaluation of citizen science projects has conventionally been conducted by in-house researchers or third-party organisations (Fawcett et al., 2003). However, reflecting the democratic turn of citizen science projects, citizens' involvement could likewise be extended into the evaluation process. Placing citizens at the centre of evaluation shifts how evaluators see their role. If evaluation is shared *with* and designed *with* citizens, everyone can better understand what works for citizens' involvement, what barriers (e.g., local customs or interests) might stand in the way, and what citizens need from other project stakeholders. For example, the 'Bristol Ageing Better' programme, a partnership of people and organisations working to reduce isolation and loneliness among older people in Bristol (UK), purposefully recruited older volunteers to evaluate the programme, built engagements in the programme on principles of asset-based community development, and trained community evaluators to assess impact and contribute to outputs and dissemination (Beardmore et al., 2022).

Fawcett et al. (2003, p21) outlined an interactive and iterative six-component framework for participatory evaluation: "(a) naming and framing the problem/goal to be addressed, (b) developing a logic model (or theory of practice) for how to achieve success, (c) identifying evaluation questions and appropriate methods (what do we want to know and how will we know it), (d) documenting the intervention and its effects (what are we doing, is it making a difference), (e) making sense of the data (what are we seeing, what does this mean), and (f) using the information to celebrate and make adjustments". This model of evaluation can be used to assess the degree to which citizen science projects are participatory and how participation can be further developed.

THE WECOUNT PROJECT

This paper presents the case study of an urban mobility citizen science project that has involved citizens in more participatory ways, from technical development to citizen engagement and evaluation.

WeCount (*Citizens Observing Urban Transport;* 2019-2021) was a Horizon 2020-funded Science with and for Society citizen science project in five European case studies (Leuven in Belgium, Madrid/Barcelona in Spain, Ljubljana in Slovenia, Dublin in Ireland, and Cardiff in the UK). The project aimed to empower citizens to take a leading role in the production and analysis of mobility data and to use the evidence for action on improved urban mobility in their neighbourhoods.

The project teams in each case study planned to recruit citizens and community organisations through face-to-face engagement, making targeted efforts to work with schools and with community groups, specifically groups engaging with people living in areas of low socio-economic status. However, COVID-19 restrictions prevented this from happening and citizens were instead recruited through traditional and social media. Recruitment involved using previous networks of contacts and relevant mailing lists, as well as advertising the project on Twitter and Facebook. Despite the pandemic, community organisations and local government relationships remained key to brokering connections with people living in areas of low socio-economic status. Participants interested in taking part in WeCount registered via an online platform and were asked to upload a photo taken from a window that faced a road. Photos were then assessed for suitability: having a clear view of the road with no trees or other obstacles that could interfere with the traffic sensor.

Participating citizens who lived in homes with a suitable road-facing window were given a Telraam, a low-cost traffic counter comprising a Raspberry Pi computer and a camera; this was developed by Transport and Mobility Leuven[1] before the project. The Telraam counts the number and speed of cars, large vehicles, cyclists and pedestrians passing the camera; it thus provides cheap and accurate data at a far greater temporal and spatial scale than is possible in classic traffic-counting campaigns. The data gathered by the Telraam were made freely available on a public platform[2] that allowed citizen scientists to access their own and their neighbours' data, which they could use as evidence to spark collective action and influence decision-makers. Citizens were involved in co-designing the data platform, collecting and analysing the data, and engaging with key stakeholders.

WeCount citizens took part, often as clusters of neighbours, in several workshops (held online due to the COVID-19 pandemic) to build connections, formulate problems, learn how to assemble the sensor, understand how to interpret and analyse the data, and share knowledge on how to advocate for policy and behaviour change. The engagement process (Figure 1) was piloted in two pilot case studies to allow citizens' questions and feedback to inform and influence the development of the sensor, workshops and events.

THE WECOUNT EVALUATION

The evaluation methodology of WeCount comprised three parts: direct evaluation, monitoring, and self-reflection by staff (Sardo et al., 2021). Evaluation methods such as registration forms, feedback on workshops, online survey and interviews with citizens formed part of the direct evaluation; while monitoring relied on collecting number of attendees and demographic information for workshops, social media and website analytics and specific activity relating to the Telraam sensor (such as active counters, drop-out rates, etc.). Finally, the self-reflection part of the evaluation focused on the WeCount team, using tools such as reflective logs after workshops and events and in-depth interviews with staff (Figure 2 provides a detailed account of the evaluation methods used).

It took an integrated approach, documenting direct (e.g., in workshops) and indirect (e.g., on social media) citizen engagement, citizens' experiences (e.g., time, enjoyment, knowledge improvement, technology development), and behaviour change (e.g., taking action with the data). The extent to which power and resources had shifted into community hands was also noted.

The evaluation of the WeCount project was detailed and in-depth but due to time and pandemic related constraints, it was not as participatory as it could have been. In WeCount, citizens have not contributed to the design and development of the evaluation framework, however they were active participants in elements of the evaluation process. Looking at the six-component framework for participatory evaluation by Fawcett et al. (2003, p21), participants took part in "(d) documenting the intervention and its effects (what are we doing, is it making a difference), (e) making sense of the data (what are we seeing, what does this mean), and (f) using the information to celebrate and make adjustments".

1 https://www.tmleuven.be/en/
2 www.telraam.net/en

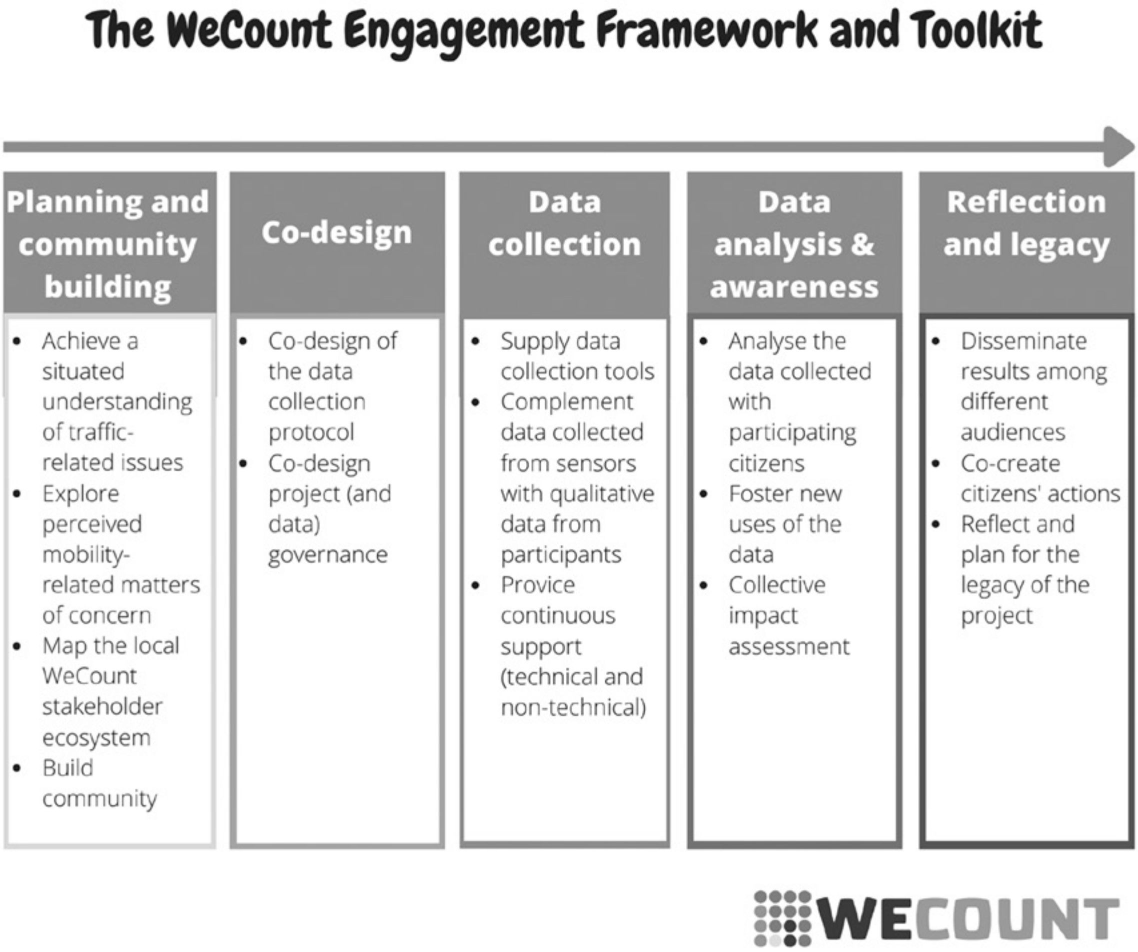

Figure 1 – The WeCount engagement framework and toolkit.

DIRECT EVALUATION AND MONITORING

Ethics Approval for the evaluation was granted by the UWE Bristol Faculty Research Ethics Committee (FET 20.02.034). Everyone taking part in the project and the evaluation received Participant Information Sheets and gave their informed consent to participate. Young people under 18 years consented to participate along with their parents' informed consent as well.

A variety of methods were used to evaluate the individual events and activities and the project overall. The evaluation methodology had to work across case studies and in different languages, collect high-quality evaluation data from events and activities, and from participating citizens and the project team.

The evaluation methods were selected based on *citizen personae* (idealised descriptions that help project designers understand users' needs, interests and desires (Nielsen, 2019)), those methods identified as appropriate to gather citizen feedback, anticipated return rates, and ease of use by project leaders in different cultures and with different existing evaluation expertise. The personae were drawn from the literature and developed by the project team, supported by an external expert. The *personae* were drawn from the literature and developed by the project team, supported by an external expert. *Personae* are used for design processes to develop products and tools that meets the users' needs and goals. The choice for using *personae* in the tool design process was based on the work by Long (2009), who claims that '*personae* strengthen the focus on the end user, their tasks, goals and motivation. *Personae* make the needs of the end-user more explicit and thereby can direct decision-making within design teams more towards those needs' (Long, 2009, p10). Since its inception in the 1990s, the persona-method has evolved from a method for developing IT systems to its use in many other contexts, including product development, marketing, communication planning and service design. Using the *citizen personae* approach the team set up several workshops, called TelraamLabs; these aimed at getting to know the citizens better, their motivations to take part and any needs in terms of support. The first TelraamLab led to identifying five personae, based on their different needs. Following TelraamLabs identified a need for a community platform, to foster networking and learning. Citizens worked together to identify and create building blocks for a Community Platform. A final TelraamLab saw these building blocks discussed in detail, with a clear view of goals and content for each building block. The *citizen personae* was a positive approach which allowed the WeCount team to forge stronger relationships and better understand the needs, motivations and priorities of the participating citizens. It is a time-consuming approach, but one that provided important user-centered input with level of participation.

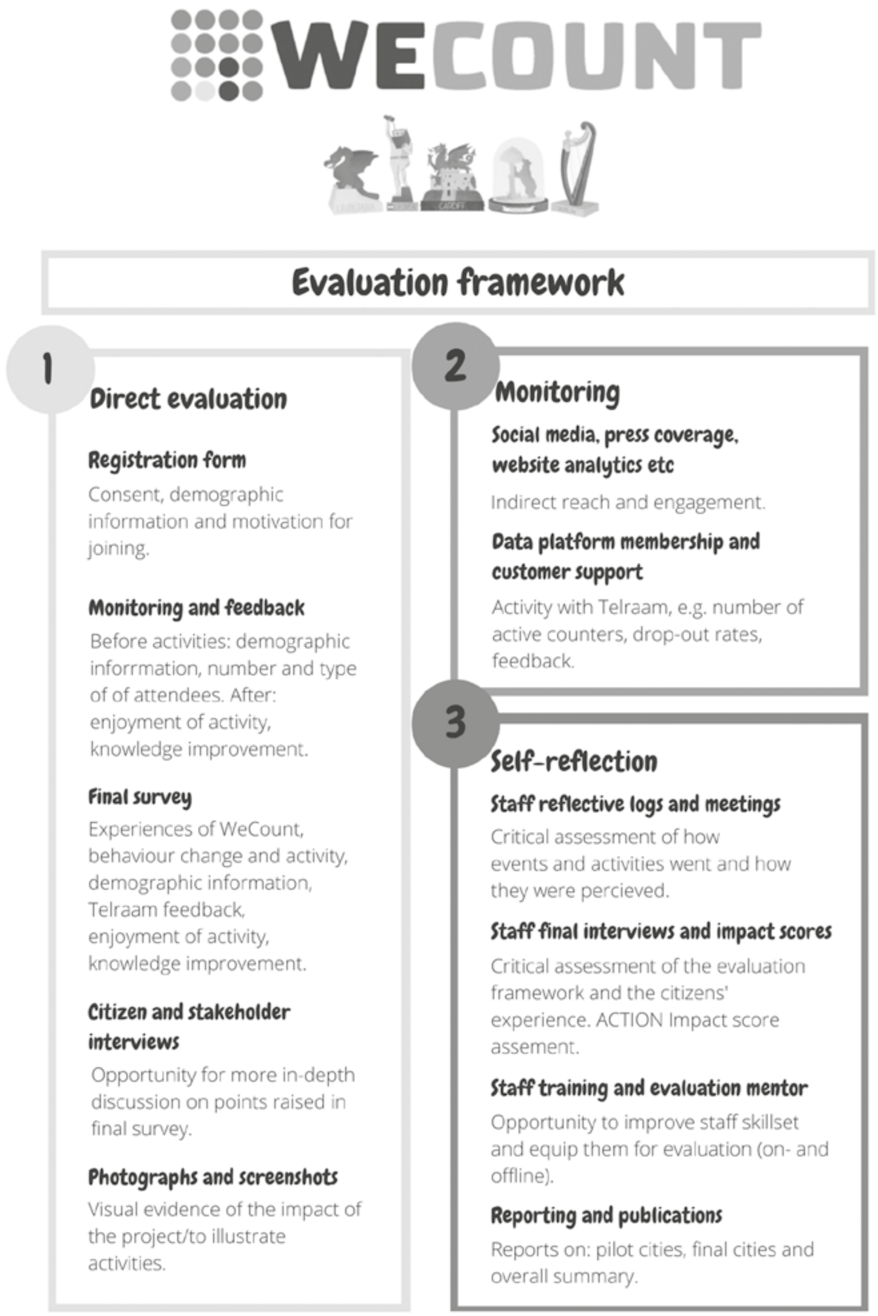

Figure 2 – The WeCount evaluation framework.

Cross-sectional mixed methods surveys were conducted in all five case studies, using an online survey tool (Qualtrics[3]). The survey was designed in English and translated into the local languages of each country. Most questions were in closed format, as this is more inclusive for a variety of different participants (De Vaus, 2002). Open-ended questions, which allow participants to provide answers in their own terms (Grand and Sardo, 2017) were included but were kept to a minimum since they tend to have a lower response rate (Groves et al., 2004). The survey results were translated back to English, cleaned using Excel (2016) and analysed thematically with NVivo 12 before running descriptive and analytical statistical tests using SPSS 26. The online survey proved a successful tool to collect feedback from citizens across all case studies. The balance of open and closed questions enabled the participants to give quick and focused feedback.

Semi-structured interviews were conducted to directly access the observations, insights and experiences of the participants (Tong et al., 2007) in their own terms (Groves et al., 2004). The evaluation team offered training to WeCount staff to enable them to conduct interviews

3 https://www.qualtrics.com

in their own language. Interviews were conducted online or as phone calls, transcribed verbatim and then translated into English if necessary. Conducting interviews with a small number of citizens in each case study made the task manageable for local teams. The in-depth data collected via interviews added richness and detail to the online survey data.

The WeCount staff, many of whom had no evaluation experience, later reflected on the evaluation activities and process, and their perceived success. The Evaluation Framework was praised for being very comprehensive, alongside a helpful evaluation mentor. Some staff members thought that the framework was too rigid, and that they would have benefitted from more training or face-to-face support (although they noted this was difficult due to COVID-19). The data from the staff reflections are not directly reported here but were triangulated to inform the citizen data analysis. The full results are included in the final project report (Sardo et al., 2021).

RESULTS

PARTICIPANT REPRESENTATION

WeCount engaged 1,988 citizens during the project. Levels of engagement varied, ranging from the high involvement of 368 'counting citizens' who installed a Telraam sensor in their home (Barcelona/Madrid (n=50), Cardiff (n=70), Dublin (n=80), Leuven (n=86), and Ljubljana (n=82)), to the low involvement of citizens who simply received newsletters (n=163).

There was an almost even split of male and female participants (51:49%). Many participating citizens were under 16 years old, due to efforts made to reach out to children living in areas of low socio-economic status. The age range of 'counting citizens' was broad, although the largest group (28%) was in the age range 35-49 years, which might be due to the technical nature of the sensor and the skills needed to set it up. Postcode data from Dublin and Cardiff indicates that 25% of the Telraams in those cities were distributed to people living in neighbourhoods of low socio-economic status, which is where higher levels of air, noise, and traffic pollution are usually observed (Barnes at al., 2019; Braubach and Fairburn, 2010) Neighbourhood data were not available for other cities. The educational level of counting citizens was exceptionally high; 81% of these participants held a first degree or higher. Furthermore, only 9% of participants reported their occupation as skilled manual, semi-skilled or unskilled.

The end-of-project evaluation survey was completed by 236 citizens; most (75%; N=178) were 'counting citizens', 18% (n=43) identified as 'involved' (e.g., took part in workshops/evaluations), and 3% (N=7) identified as 'local champions' who helped to recruit and support others. The demographic data for the survey respondents largely matched the overall data for all citizens who participated in the project, although they were skewed towards men (61%) and the highly educated (89% with a first degree or higher). In addition, 37 citizens responded to the request for interviews; 62% (n=23) identified as male and 38% (N=14) as female. All the interviewees were highly educated (holding a first degree or above). The modal age category (for those who gave their age) was 35-49 years.

PARTICIPATION AND CO-CREATION

Thematic analysis (Braun and Clarke, 2006) of the citizen interviews was conducted; members of the project team independently reviewed the data to develop coding themes which were combined into six inductive themes for analysis. Two themes related to citizens' motivations for joining the project; citizens either identified as being 'Data Lovers' and were taking part for the technology and counting information or wanted the data to provide 'Traffic Evidence' which they would use in local campaigns. Two themes related to citizens' experiences of conducting citizen science on traffic data; 'Car-free Campaigning' discussed the various ways that citizens either were using, or hoped to use the data to evidence their car-free or speed reduction campaigns; 'Creating Community' discussed how the citizen science project had connected people locally through the workshops or campaigning, or in some cities during the COVID-19 pandemic, citizens felt they had missed out on community opportunities. Two final themes offered feedback on the 'Project Operation' and 'Using the Telraam', from the participants' experience of being citizen scientists. The qualitative interview data were triangulated with quantitative data from the survey and the datasets are presented in an integrated manner in this section.

MOTIVATIONS FOR JOINING WECOUNT

The survey showed that although motivations for joining WeCount varied, the main motivations were having an interest in sustainable mobility (N=100; 22%), wanting to contribute to research (N=94; 21%), wanting to make a difference (N=89; 20%) and wanting to count traffic (N=81; 18%). An interest in science/citizen science or technology was less of a motivation for joining, which is understandable given that the project was promoted to, and thus attracted, citizens who wanted to make a difference to urban transport and mobility. Men were significantly more likely than women to join WeCount because of an interest in technology[4].

There was a significant difference between higher educational attainment and science-related motivations[5]. In other words, highly educated people are more likely to suggest these are their motivations. There was no significant difference between age and motivation.

A more participatory approach to the survey evaluation would likely have uncovered additional motivations, as the evaluators included what they assumed were the motivations to participate in WeCount.

Most of the citizen interviewees were motivated to join WeCount because they wanted to gather objective evidence about the traffic on their street. Many told stories about discussing levels of traffic, speed, noise and air pollution with policymakers, but being unable to prove them:

4 Perhaps rather unsurprisingly, there is a highly significant difference between gender and an original motivation in technology (Mann-Whitney U= 4150.5, n1=n2=236, P <.005 two-tailed)

5 (Kruskal Wallis test): "to count traffic" (H (4) = 13.22; P = .01), "to contribute to research" (H (4) = 10.26; P = .03), and "an interest in science/citizen science" (H (4) = 10.26; P = .01)

It's an additional motivation to have the data… They can't deny certain things anymore. That gives you a weapon in your hands – although that might be somewhat aggressive wording. An additional instrument, something you can use.
(LeuvenCitizen Interview04)

It is a busy road, there's no denying that, but it's actually busier than we thought… it's really revealing and hopefully, it can be building and used for some kind of constructive change, yes, that's what we're hoping.
(CardiffCitizen Interview07)

MOTIVATIONS FOR REMAINING WITH WECOUNT

Among survey respondents, the most common reason for remaining with the project was that they liked 'being part of a research project' (N=144; 34%) (Figure 3), followed by feeling that they were 'making a difference' (N=80; 19%). Interestingly, 'technology' (which was ranked sixth for motivation to join) came third (N=75; 18%), which suggests that the experience of using the Telraam and associated tools and platforms during the project offered participants some added value. Gathering evidence to support a campaign (N=65; 15%) came fourth, which probably relates to respondents' existing interest in sustainable mobility; that is, they might already be active in this space and have been motivated to join to further their campaigning.

There is no statistical difference between age or educational attainment and favourite aspect, however there is for sex[6]. Women were statistically more likely than men to consider collective problem-solving to be their favourite aspect of WeCount, this indicates that women enjoyed working with others to come up with solutions for traffic issues in their local areas.

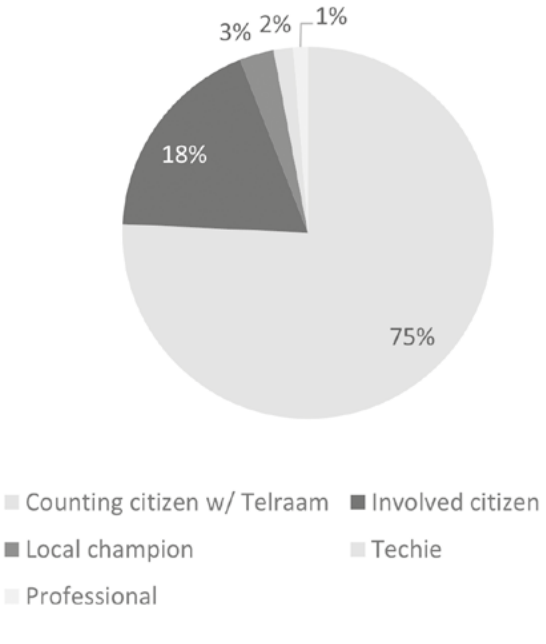

Figure 3 - Favourite aspect of WeCount.

The interview data reinforce the survey data; most participants said that they had enjoyed being part of the project. They felt that the project had operated smoothly, with good communication between staff and citizens. Many described the data from the project as an excellent legacy:

My whole objective out of this is to quantify how bad the problem is so we can start to do something about it. One of my goals (…) is that I can start presenting the data and present it in a way that illustrates the scale of the problem but then also present it in a way that if we enact certain solutions that favour active travel, we can also reduce the traffic as well.
(DublinCitizen Interview06)

Taking on board citizens' feedback, these ideas were developed by the project into an advocacy and policy workshop which was co-developed with citizens and ran at the end of the project to support community building.

PROJECT CO-DEVELOPMENT

Drawing on asset-based community development and community organising principles, 843 WeCount citizens took part in 56 events and workshops across the five cities. The Leuven case was also a pilot study, so its data were used to inform and adapt the development of later workshops and events. There were nine co-design workshops, 21 kick-off sessions to introduce the project, set citizens up with sensors and ask them about local issues they wanted to tackle as a community, nine data analysis workshops, four Application Programming Interface (API) workshops (several technology-literate citizens helped develop the API codes) and 13 young people's events. Videos and how-to guides were also created to support citizens with installation, a process many found daunting at first.

Where possible, participants were asked to rate their experiences of the workshops, using rating scales graded from 0 (poor) to 5 (excellent). Across all the cases, the mean responses for the citizen ratings are below:

- enjoyed the workshops (4.5)
- felt their input was valued (4.6)
- felt capable of installing a Telraam after the relevant session (4.3)
- felt capable of understanding the Telraam data (4.6)
- felt their knowledge was generally strengthened (4.6)
- felt better able to act based on the data (4.4)
- believed their input would be used to influence urban transport and mobility (4.4)

Using *citizen personae* created through a co-design process in a "getting to know you" session with Telraam counters, the Leuven team set up workshops to facilitate networking, learning, and inspiration. In these workshops, citizens used cardboard boxes and craft materials to depict what should be in a Telraam community platform. These visual representations formed several of the building blocks that eventually made up the community platform, which was finalised in the third and final workshop (Figure 4).

6 Kruskal Wallis testing found that working collectively to solve problems was highly significant between sexes (H (1) = 9.76; P = .003). Post hoc Mann Whitney testing found that the mean score for this favourite aspect is on average -.209 points lower for men than for women. This mean difference is significant at the 0.05 level (P = .013).

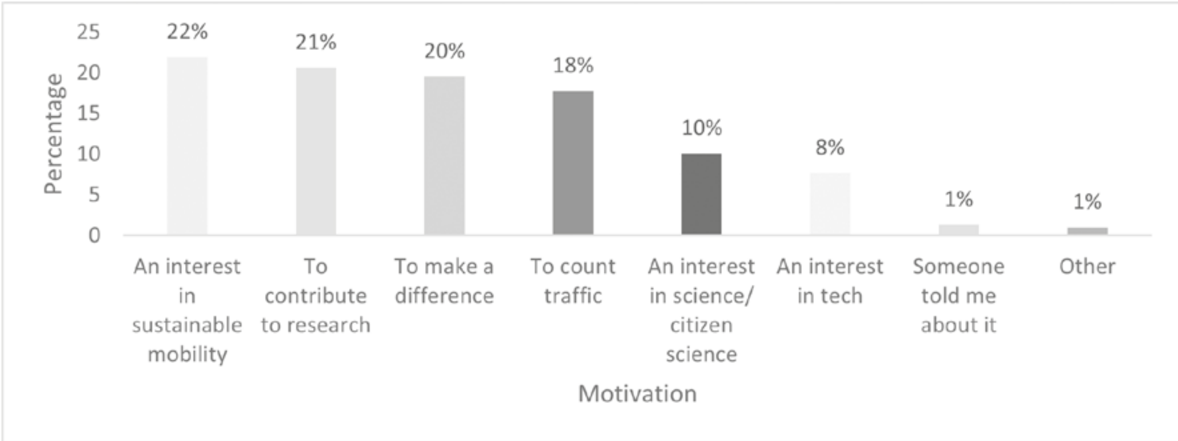

Figure 4 – Building blocks of the WeCount platform.

The data analysis workshops were co-led by the project team and citizen 'community champions'. The community champions (citizens who were particularly engaged, for example, those who supported neighbours throughout their engagement with WeCount) presented their data and discussed how they were using them to call for change in their area. Citizens tended to focus on traffic-related topics, such the impact of roadworks, speeding, traffic filters and high traffic volumes. Citizens were able to deep-dive into the data, looking at the influence of time of day, school holidays and lockdown restrictions on the figures. Using the data, citizens were able to model and visualise potential scenarios, pose questions that allowed them to understand how unsafe people might feel when using roads in certain areas, and debate possible solutions. For example, in Cardiff citizens compared the speed limit against the data they received to determine if vehicles were speeding or not (Figure 5) and were able to visualise the number and type of vehicles speeding (Figure 6).

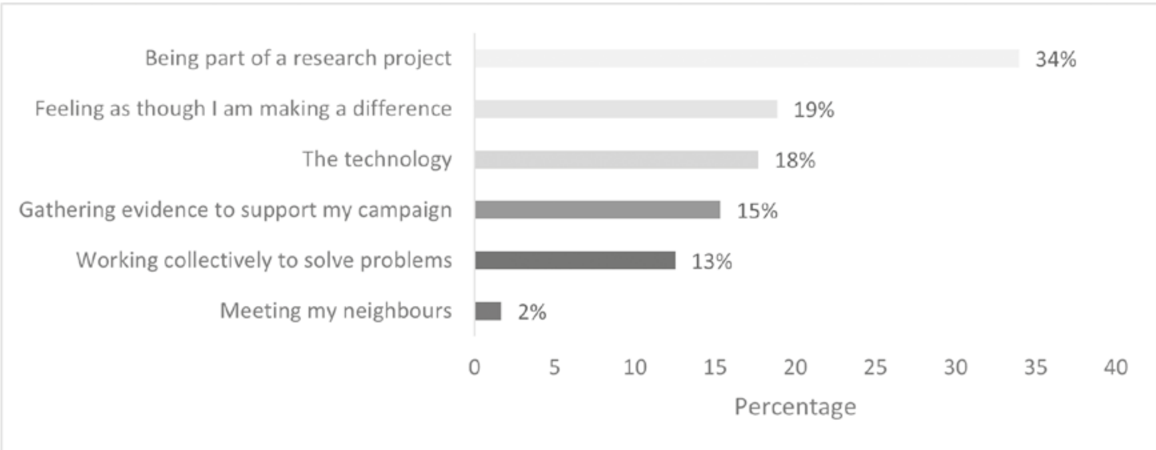

Figure 5 – Visualisation created by Cardiff citizens.

The approach taken here is an example of real co-creation, putting the data in citizens hands and supporting them to analyse it and draw their own conclusions.

Some citizens talked about how they worked with data or presentations for their living and so were comfortable with campaigning for social change. This triangulates with the demographic data on highly educated participants, which the citizens themselves noted.

> *That's the thing I really enjoyed, but I have professional experience in presenting data and my background is in engineering as well, so I have training in that, but people might not. I think maybe providing support for people in how to present the data and the evidence, because obviously, you know yourself, the story you can tell with the data is the most important thing and how you present it to bring people along with us.*
>
> (DublinCitizen Interview 07)

Having identified a need from the citizens for more knowledge on advocacy the project team and citizens co-developed an advocacy and policy workshop, which ran at the end of the project. After these workshops, one citizen group set up a WhatsApp group and created a declaration that they presented in a unified voice to their local council, while another group co-designed a citizen engagement activity using analogue data displays, which inspired a group in another city to create a similar activity. Overall, 10% of the citizens surveyed took actions ranging from hacking the sensor, to applying for funding, to lobbying decision-makers for urban mobility improvements.

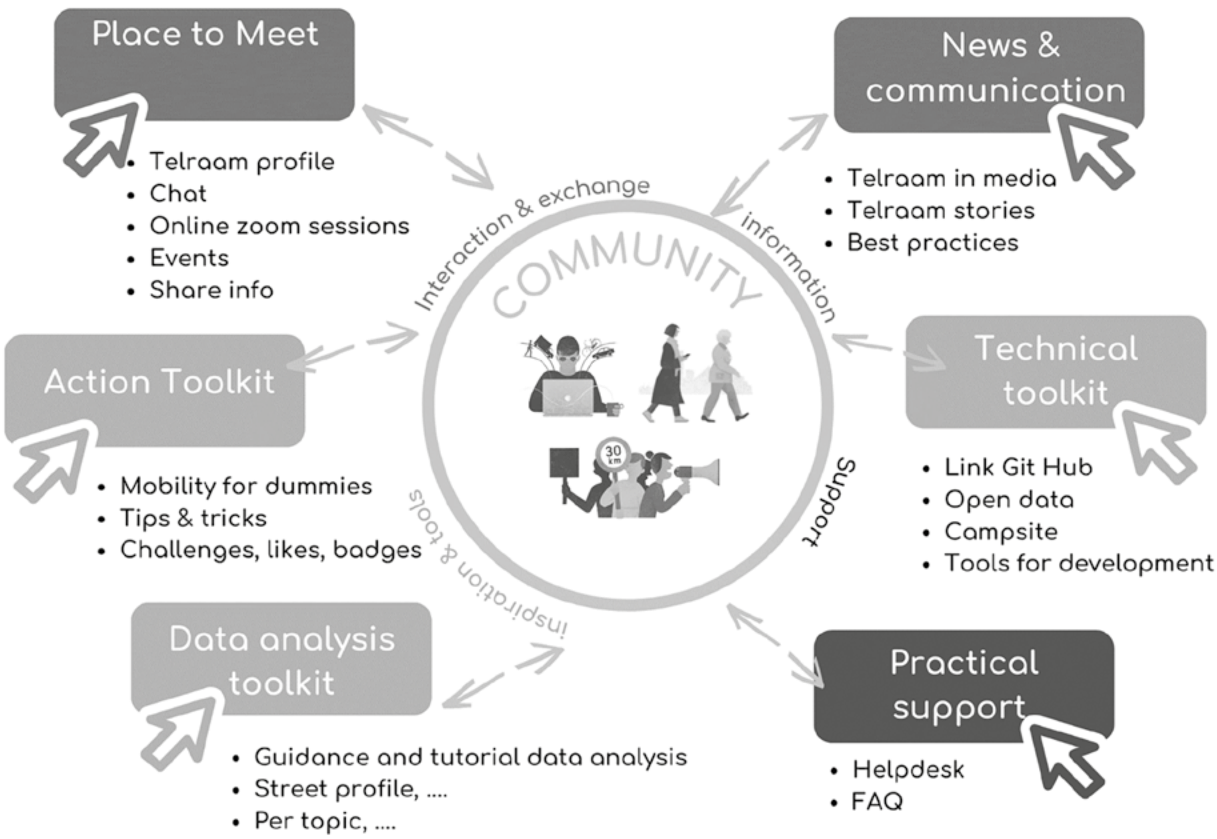

Figure 6 – Visualisation created by Cardiff citizens.

Many of the citizens have formed connections and have continued counting beyond the end of the project; 56% of the sensors are still in operation at the time of writing. In the citizen interviews, several people stated that they intend to continue their involvement with their community and their city councils:

> *I felt I belonged to a community that was contributing by providing additional value that serves to perform some type of analysis subsequently.*
> (MadridCitizen Interview6)

> *It's interesting to hear all these people's ideas. For us, it's very centred to Leuven, but then you can really see how people … This is a very interesting thing. You organise an evening meeting in Leuven. The weather was awful that time and still people make an effort to go there for a voluntarily project to exchange ideas with others. It was very nice to see that the things that were discussed there, were actually picked up and developed further.*
> (LeuvenCitizen Interview01)

When citizens stop counting, they are asked to complete an offboarding survey, including reasons to opt out. This form is only rarely filled in, we cannot give an informed overview of reasons for quitting. Informally, we know that some citizens only planned to use the sensor for the duration of the project and stopped when the project finished.

While the COVID-19 pandemic restricted in-person end of project wrap-up meetings and celebrations, all the citizens who took part were thanked, and their success stories captured in blogs and videos[7].

DISCUSSION

Citizen science appeals largely to well-educated people with an interest in technology and research (Haklay, 2018). This was demonstrated in WeCount; its participants were mostly highly educated, middle-class professionals; just 25% of the sensors were deployed in neighbourhoods of low socio-economic status, although we cannot say for sure if the users were from low socio-economic backgrounds. This skew might be due to the fact that the technology involved presented a barrier to entry for under-represented groups, as participants needed to have access to high-speed Internet and possess a degree of skill and confidence in handling technology (Barnes and Chatterton, 2017; Barnes, Chatterton and Longhurst, 2019; Dawson, 2014). In addition, the original/pre-pandemic recruitment strategy was heavily affected by pandemic-related restrictions, meaning limited access to citizens from low socio-economic status. Another factor to bear in mind is that the project itself was, by nature, excluding people: it was advertised as a citizen science project focused

7 https://www.youtube.com/channel/UCgsAlkg7JIQd597Wy1C5q1A

on sustainable mobility, therefore mostly appealing to people interested in these subjects.

Nevertheless, WeCount succeeded in several aspects of participation: citizens were able to name and frame a problem to be addressed or goal to be reached that was relevant to their lives, for example focusing on specific place-based issues (e.g. traffic near a school), and they came together to set up the sensors, analyse the data, reflect on ways to improve advocacy for behavioural and policy change, and feed in, via the survey and interviews, their experiences and thoughts on how to improve the sensor and the project. Based on this typology, WeCount can be considered as an empowering/democratic approach to citizen science (Table 1). Yet, two flaws in the design became apparent during the project which throw caution to this designation. First, as mentioned, the prevalence of well-educated individuals with specific interests in sustainable mobility. Second, while the project sought to empower citizens from the start, there were not opportunities for them to co-evaluate the project. Nor was it always possible for them to come up with issues to solve as a collective as some kick-off meetings had representation from people from all over the city (and sometimes beyond). This latter issue could be largely overcome with in-person workshops in the future held in specific community spaces, which were not possible due to the restrictions imposed by the pandemic.

To make the project more inclusive would require more time and energy to reach out to marginalised communities and nurture those relationships – and thus a longer project timeframe. Citizen science projects are historically unrepresentative, but this needs to change if we are to address the intersectionality of sustainability challenges with ethnicity, gender, disability, and economic status. Thus, in addition to a longer timeframes future citizen science projects will need to consider training requirements and finding ways to financially recompense gatekeepers to, and members of, under-represented communities (Griswold et al., 2020; Dawson, 2014). The purposeful design of WeCount, centred around deep involvement through community building and training lent itself to a sense by both citizens and the project team that it increased their motivation and the likelihood for it being sustained after the project ended.

A more fully participatory and co-created evaluation process meanwhile, would require citizen involvement to be embedded from the start of the project (Fawcett et al., 2003) to support co-creation of evaluation questions and appropriate methods, rather than evaluation being led by professional evaluators or researchers. This might well require citizen evaluators to be trained in evaluation design and methods and paid for the time they spend on co-creation or evaluation (Griswold et al., 2020; Dawson, 2014). If data on citizens' aims, objectives and subsequent actions had been included in the WeCount evaluation, they might have enabled greater insights. From the involvement participants did have, our findings indicate that the deeper their involvement of participants in the evaluation, the more we learn about their experiences and involvement. Participants also feel more connected to the project and the process, when they are involved in co-creation. Despite this lacuna, the WeCount evaluation methodology was flexible, capable of adaptation for each case study and offered the project team (many of whom had no experience of evaluation) training in evaluation methods, which offers lessons in how similar training and flexible design could be extended to enhance co-creation and citizen participation in future evaluations. There is room to make the evaluation more co-created but, by involving and training WeCount staff members with a range of experience, lessons were learned that will enrich co-creation in future projects and evaluations.

Moreover, WeCount's engagement framework facilitated co-design and, despite the lack of official community evaluators, the evaluation framework was able to draw on citizens' input in defining personae, shaping the technology, framing engagement processes and sharing lived experiences. Further steps could be taken in the future to make similar project evaluations more participatory and in line with Fawcett's framework (Fawcett et al., 2003). Drawing on our experience in WeCount, we argue that citizens could be involved in the evaluation from the onset of the project and, as they are recruited, asked to identify evaluation goals, how success can be measured and collaboratively choose methods and design evaluation questions. This process could initially start online, using interactive boards such as Padlet and progress to in-person discussions and focus groups.

Reflecting on participatory evaluation more generally, the use of participatory evaluation methodologies in citizen science has the potential to greatly contribute to impact assessment, as well as empower participants and build capacity. However, it is important to acknowledge that some projects may lack the capacity and resources to employ such methodologies (Nelson and Landman, 2020). Crishna (2007) argues that participatory evaluation is time consuming and requires skill-building for participants. This approach also tends to result in high volumes of data, another challenge to manage (Zukoski and Luluquisen, 2002). Therefore, participatory evaluation could lead to overburdening both the citizens and the project team.

CONCLUSION

Almost 2,000 citizens engaged in WeCount, over two years, including 368 who hosted a Telraam sensor. The largest group of citizens was aged 35-49 years, although a significant number was under 16 years old, due to the efforts to reach out to children living in areas of low socio-economic status. A quarter (25%) of the Telraams were installed in neighbourhoods of low socio-economic status. Citizens were highly educated, with 81% having at least a first degree, and many were either active campaigners on sustainable mobility or were interested in being part of a research project and making a difference.

While the citizen scientists did not faithfully represent the wider population of their country, they are a cohort of motivated people, who continue to count traffic and collect sensor data. Citizens' input to the design of the sensor and project workshops has resulted in a citizen science model for urban mobility that could be refined for deployment in other cultures and contexts. Citizens are looking to find ways to make their collective voice heard, such as using sensor data to apply for funding to meet their community's needs and challenges. Citizens are also displaying evaluation skills. However, citizen science projects would benefit from involving citizens in the evaluation process from the outset, for example identifying priorities and evaluation questions, as well as in developing a theory of change that would define the training and skills needed to support citizens in their evaluation journey. They would also benefit from financially compensating citizen evaluators and community champions who can amplify the voice of underrepresented groups. The next step is for citizen science projects to take on board these lessons, observing whether empowerment through not only knowledge and tools for collective action, but the finances to participate, leads to a more equitable seat at the decision-making table.

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

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ACADEMIC MANUSCRIPT

ABSTRACT

This paper presents a multidimensional methodology for assessing the scientific, social, economic, political and environmental impacts of citizens 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 (Sauermann 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 at al., 2009a) and the attention for this phenomenon is growing among researchers and decision-makers (Hecker at 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 at 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[1], 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 leasted 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[2]. 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[3].

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)[4].

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[5]. 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)[6]. 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[7]. 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.action-project.eu

2 In talking about engagement in scientific activities (Bonney at 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#.Yotz8WBBxpI

6 Other source of inspiration have been: https://www.artsculturefinance.org/wp-content/uploads/2018/09/Impact-Management-Canvas.pdf and https://www.threebility.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/volunteers), 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 at 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[8]". 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.

8 https://actionproject.eu/citizen-science-pilots/students-air-pollution-and-diy-sensing/

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 studies 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 exanimated were able to be inclusive: the Water Sentinels[9] 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[10] 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[11], 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[12], 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[13] 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

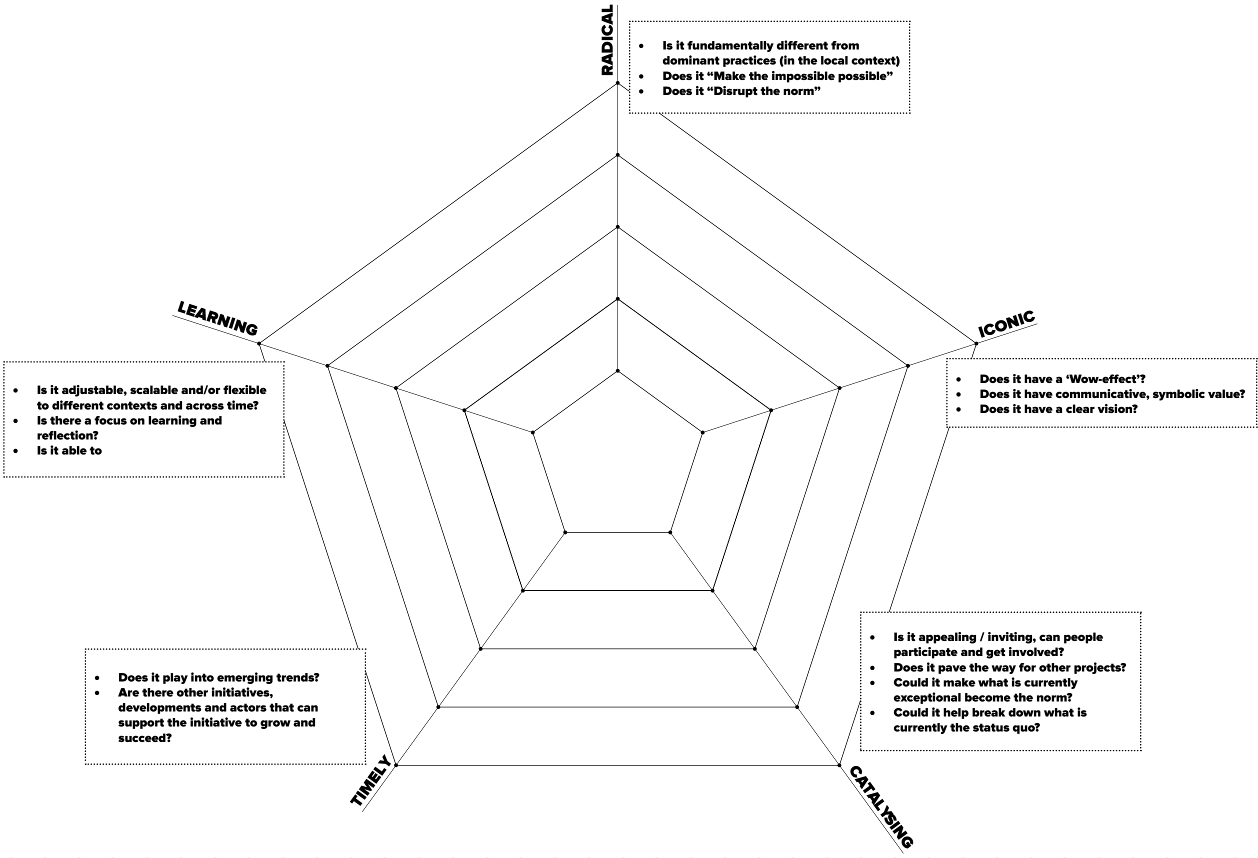

Figure 2 Framework to assess transformative potential, SIC Public Sector Innovation Blog

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

14 www.action-project.eu

EVALUATING CITIZEN SCIENCE INITIATIVES THROUGH A CITIZEN SCIENCE-BASED APPROACH

PRAXIS REPORT

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ABSTRACT

Citizen Science (CS) has gained increased recognition over the last two decades. This turn is occurring in strong connection with the profound transformations that have affected science over the last few decades, leading towards a new social model of science, characterised by greater openness to society regarding research content, actors involved, research processes, and expected societal and economic impact. CS is at the centre of this complex change dynamics as a tool that strongly sustains the shift towards the "open social model" of science, supporting a new approach to the science-society relationship. However, CS is rarely evaluated for its long-term structural effects on science and the science-society relationship. This article addresses this topic, having as a point of departure the ongoing EC-funded Step Change project, aimed at promoting five Citizen Science Initiatives (CSIs) in different research fields (health, energy, and environment). Under the project, an Evaluation Framework has been developed, shaping the evaluation process as a citizen science project by adopting a developmental and participatory approach. The Evaluation Framework is organised into two different but intertwined levels, one focused on the evaluation of the individual CSI (analytical level) and a second aimed at identifying recurrent patterns of obstacles, facilitating factors, or a mix of them (neutral situations) across the CSIs (cross-cutting level). While the analytical level is intended as a service to better implement the CSIs, the cross-cutting level is intended as a research process to generate new knowledge on how CS could serve as a tool for a better anchorage of science into society.

INTRODUCTION

Citizen Science (CS) has seen a "new dawn" in the last two decades (Silvertown, 2009), as witnessed by, e.g., the rapid diffusion of CS projects in different research fields (Cooper, 2016; Kullenberg, & Kasperowski, 2016) or the launch of national and European programmes in support of CS (Kieslinger, et al., 2018; Trojan, Schade, Lemmens, & Frantál, 2019).

This turn is connected to the profound changes affecting science in late modern society that have been the subject of various interpretative models, including, e.g., the Mode 1 - Mode 2 model (Nowotny, Scott, & Gibbons, 2001), or the Post-academic Science (Ziman, 2000). Overall, these models describe a still ongoing paradigm shift from the consolidated social model of science – often associated with the image of the "ivory tower" – in which science enjoyed an exclusive authority in validating scientific knowledge and a high level of autonomy from the rest of society, to a new "open social model" in which science is engaged to match the expectations, needs, worries and problems of society, is transparent and responsible for the potential and actual use of scientific products, and is open to the cooperation with (and is also strongly dependent on) political, economic, and societal stakeholders.

Different strategies have been developed to propel, speed up, or manage this shift, including the adoption of a neoliberal reorganisation of research systems (Morrish, 2020; Troiani, & Dutson, 2021) and the development of responsible research and innovation policies (Von Schomberg, 2013; Stilgoe, Owen, & Macnaghten, 2013).

CS is at the very centre of this complex dynamics as a tool sustaining the shift towards the new social model of science, especially for the capacity to develop participatory and communication mechanisms (Woolley, et al., 2016) able to favour a "democratization of science" (Haklay, 2015; Strasser, et al., 2019).

However, the contribution of CS to orienting a new social model of science – i.e., its systemic impacts on science– is far from being evident. There are serious barriers to making CS a business-as-usual approach in R&I and little attention has been given to its potential structural effects on science and science-society relationships. This is also because the same concept of CS includes a wide variety of practices (Wiggins, & Crowston, 2011; Shirk, et al., 2012; Schaefer, & Kieslinger, 2016) with highly variable potential impacts.

This article aims at contributing to the reflection on this topic, having as a point of departure the evaluation framework developed under the ongoing EC-funded Step Change project[1]. The manuscript comprises four main sections, respectively devoted to a short presentation of the Step Change project, the concepts, and assumptions at the basis of the evaluation framework adopted, the structure of the evaluation framework, and a discussion about critical aspects and limits of the proposed approach.

1 Step Change received funding from the European Union's Horizon 2020 research and innovation programme (grant agreement No 101006386)

THE PROJECT AND ITS RATIONALE

Step Change is a 3-year long project led by the University of Primorska (Slovenia). It started in April 2021 and involves five CS Initiatives (CSIs) in different research fields (health, energy, and environment) to be held in five countries (Germany, Italy, Slovenia, the United Kingdom, and Uganda).

The project assumes that science always entails the involvement of laypeople and therefore "non-technical" knowledge (Knorr-Cetina, 1982) and the co-existence of different standpoints, no one of which is more objective than others (Harding, 1992). The need to fruitfully coordinate them dramatically increases when the scientific effort – as growingly occurs in contemporary science (Nowotny, Scott, and Gibbons, 2001) – is aimed at addressing the critical fields where human and non-human factors are deeply entangled (environment, health, artificial intelligence, biotechnology, etc.) and where highly contested social issues emerge. In such cases, incorporating the standpoint of social actors, especially marginalised people (Harding, 1992), is essential to capture aspects of the situation that otherwise could escape from scientific analysis.

However, the recognition of the presence of different standpoints does not imply that "objective" knowledge is impossible (Rolin, 2020). Rather, it implies that objective knowledge is closely dependent on increased control over the transepistemic dynamics embedded into the social relationships established around and within the research process.

In this framework, CS can play a structural role in the way R&I is implemented. Differently from other participatory approaches in research, CS is explicitly intended to influence the most intimate mechanisms of science (its practices and contents), with strong implications at an epistemic level (use of non-scientific knowledge to enhance scientific products), societal level (interactions between scientists and laypeople; social impact of scientific research), and institutional level (CS-related changes in research organisations and other involved organisations). These features make CS one of the few research approaches that are aware of the transepistemic dynamics of science and able to manage the power relations, bias and tensions connected with them. Moreover, they also show how much CS is connected and partially overlapped with the principles and practices of participatory action research (Albert et al. 2021).

However, a question that still needs to be investigated is whether and under what conditions CS can have a systemic impact on science and help manage the transition to a new social model of science. Indeed, the risk is to consider CS as a specific research approach that has no relation with and influence on conventional research practices and policies as well as science-society relations.

It is precisely this potential role of CS that the Step Change project aims to explore. For this reason, the project is developed along two parallel axes. The first axis focuses on the design and implementation of the five CSIs, while the second axis focuses on citizen science itself.

BASIC ASSUMPTIONS OF THE EVALUATION PROCESSES

The evaluation process, under Step Change, is based on these same axes.

On the one side, it is conceived to support the teams in charge of the CSIs to assess their initiatives. To this aim, the developmental evaluation approach (Patton, 2010; Gamble, 2008; Preskill, & Beer, 2012) is used, since such an approach has some features which particularly fit CS projects.

- It is conceived to evaluate complex social interventions with a high level of uncertainty (and quite often CS projects are complex social interventions)
- It is not judgmental but aimed at providing the teams with proactive support during the implementation process
- It is highly participatory, fully involving the project teams in the evaluation process
- It is focused on the social processes underlying the project to identify and anticipate possible risks, rather than on recording the gap between a set of established ex-ante objectives or criteria and the actual ex-post project outcomes.

On the other hand, evaluation is understood as a powerful research approach (Byrne, 2013) to generate new knowledge about the dynamics related to CS and, more specifically, the extent to which and conditions under which CS can be a tool for socializing science (Bijker, & d'Andrea, 2009; Wyatt, 2009), that is, fostering a stable anchoring of science in society in terms of knowledge production, social interactions and institutional changes, as well as supporting the transition to an open social model of science.

These two components make the evaluation itself a citizen science initiative. Thus, evaluation is no longer only an organisational function, but also a research exercise, requiring the involvement of professional and non-professional evaluators (citizen scientists and other stakeholders involved in the CSIs).

THE STRUCTURE AND CONTENTS OF THE EVALUATION FRAMEWORK

To address this double need – supporting CSI teams and generating new knowledge on CS – an Evaluation Framework has been developed organised into two levels, i.e., an analytical level and a cross-cutting level.

ANALYTICAL LEVEL

The analytical level focuses on the individual CSI and is intended to allow the timely collection of relevant information and data to sustain the CSI teams in carrying out their activities, according to the principles of the developmental evaluation mentioned above.

Following Kieslinger et al. (2018), the analytical level includes three dimensions, i.e., the scientific dimension, the citizen science process, and the socio-ecological and economic dimension. Each dimension is assessed in terms of processes and outcomes and is organised in observation areas including a set of issues, presented in the form of questions.

- The scientific dimension focuses on the research and innovation processes of CSIs from the diverse perspectives of professional scientists and citizen scientists.
- The dimension of the citizen science process focuses on the participatory process characterising the CS approach.
- The social-ecological and economic dimension refers to processes and impacts of any kind the CSIs have, primarily at the local level, with special reference to the social sector the CSIs are focused on (e.g., health, energy, etc.).

The model of Kieslinger et al. (2018) was chosen for different reasons.

- It systematically addresses the three areas in which CS is believed to provide an added value in comparison to conventional research approaches by generating equally robust but more socially contextualised scientific results; fostering the involvement of stakeholders in both the research process and contents; and producing wider and faster social and economic impacts.
- It considers both the processes and the results of CS projects, giving the CSI teams the possibility to promptly adjust the processes to attain the expected results.
- The model is open enough to be customised to the features of each CSI. Thus, some observation areas have been adapted, some were eliminated as not relevant to the specific CSIs, and others have been added.

In the table below, the observation areas considered in each dimension are listed. The letter A, in the bracket, refers to observation areas added to the model of Kieslinger, et al. (2018). Although autonomous, the three dimensions are connected and partially overlapping.

Table 1. Observation areas included in the analytical level

SCIENTIFIC DIMENSION (SCD)	CITIZEN SCIENCE PROCESS (CSP)	SOCIO-ECOLOGICAL AND ECONOMIC DIMENSION (SED)
Process and feasibility	**Process and feasibility**	**Process and feasibility**
Evaluation mechanisms of the scientific dimension	Alignment of the CSI with the target groups and stakeholders	Target groups' alignment and active involvement of external actors
Adaptive project management	Degree of participation intensity of citizen scientists in the CSI	Collaboration and synergies with media and external CSO
Collaboration and synergies with other research groups in the same or other areas	Communication of scientific results and collaboration between professional and citizen scientists	Presence of evaluation mechanisms of the socio-ecological and economic dimension (A)
Match with planned actions (A)	Feedback to citizen scientists about research, societal, and policy outcomes of the CSI (A)	
Consideration of legal and ethical issues	Acknowledgement of citizen scientists (A)	
Financial and organisational issues (A)	Presence of evaluation mechanisms in the citizen science process (A)	
Outcome and impact	**Outcome and impact**	**Outcome and impact**
Exploitation of the scientific knowledge and publications	Learning outcomes for the participants (new skills, new competencies, etc.)	Impacts of the CSI in terms of increased social and political participation
New fields of research and research structures	Outcomes in terms of science literacy of participants	Satisfaction of external stakeholders and political actors (A)
Use of local knowledge resources	Outcomes in terms of behavioural changes of participants	Environmental impacts
Benefits for both professional and citizen scientists (A)	Participants' motivation and engagement levels	Generation of new technologies
Recognition of the limits of CS (A)	Matching with the planned targets (A)	Generation of new social innovation and practice
Satisfaction of professional scientists (A)	Satisfaction of the citizen scientists (A)	Generation of economic impacts and market opportunities

The analysis of each dimension allows drawing a profile of the CSI and thus detecting possible unbalances. For example, in some CSIs, the scientific dimension is stronger than the citizen science processes while in others the opposite occurs. Unbalances can be due to multiple factors, including the nature of the entity promoting the CSI (academic entity or civil society organisation), or the objectives pursued (predominantly scientific or predominantly oriented to social change).

Based on the Step Change experience, the choice of the teams to privilege one dimension over the others seems only partially intentional, indeed it is also based on implicit assumptions or orientations. Thanks to the evaluation process, the teams could reflect on issues they would not have considered and modify or confirm their deliberate choices.

The information produced through the analytical level mainly concerns obstacles and constraints hindering the implementation of the CSI, opportunities and action strategies aiming to face them, and the results of such actions. An additional effort has been made to anticipate future critical steps and to reframe the situation when the actions carried out do not produce the expected output. Most of the information is collected in the form of narratives and short texts, although specific quantitative data are also gathered. Special attention is devoted to the interaction between the involved actors (possible conflicts, tensions, coordination level), and the cognitive and emotional aspects (level of satisfaction, sense of ownership, motivations, etc.). Although a flexible approach to planning is applied, the organisational and planning-related aspects (match of the deadlines, match of the planned targets, management of the actions, etc.) are duly considered.

The analytical level is expected to provide the CSI teams with support to:

- Manage the CSI, especially for those aspects the team is less prepared to face
- Anticipate critical steps
- Develop alternative solutions when the original ones turn out to be ineffective
- Exploit the results of the CSI in terms of scientific and social impacts.

CROSS-CUTTING LEVEL

The cross-cutting level is not focused on the individual CSI but aims at identifying recurrent patterns across the CSIs, including patterns of obstacles, facilitating factors, or a mix of them (neutral situations). The underlying idea is that, although the CSIs are different from each other, the evaluation exercise can single out recurrent dynamics strongly connected to the specific nature of the CS and provide new insights into how CS could serve as a tool for socialising science, favouring a better anchorage of science into society.

In this perspective, the analysis can only be qualitative. However, since it is based on an in-depth observation of five different CS projects, it can nevertheless provide useful information to better understand the potential and limitations of CS as a tool for triggering structural changes, i.e., changes that modify relevant aspects (for example, organisational chart, norms and procedures, common practices, relations with external or internal actors, languages and symbols, etc.) of concerned organisations (research institutions, stakeholder organisations, public authorities, etc.) or research systems.

At the cross-cutting level, three components have been identified, each one focusing on different kinds of anchorage of science into society. They can be respectively referred to as the transepistemic, the societal, and the institutional anchorage.

Transepistemic anchorage concerns the capacity of CS to combine scientific knowledge with other kinds of knowledge (e.g., political, experiential, activist, traditional knowledge), preventing clashes and knowledge marginalisation (Knorr-Cetina, 1982).

Societal anchorage refers to the cooperation between citizens (non-professional scientists, stakeholders, policy actors, etc.) and professional scientists.

Institutional anchorage refers to the capacity of CS to activate institutional change processes in the concerned organisations (especially as regards the research).

The observation areas included in each dimension are listed in the table below.

Table 2. Observation areas included in the cross-cutting level

TRANSEPISTEMIC ANCHORAGE	SOCIAL ANCHORAGE	INSTITUTIONAL ANCHORAGE
Recognition of the knowledge produced by citizen scientists, stakeholders, and other actors	Mobilisation of stakeholders, other actors, and marginalised groups, in the CSI	Symbolic layer (changes in the visibility and representation of CS within the organisations involved with the CSI)
Actual use of the knowledge produced by citizen scientists, stakeholders, and other actors in the research process	Contextualisation of the CSI (in terms of problems, conflicts, policies, the influence of the social context on the CSI objectives and methods, etc.)	Interpretive layer (changes in the interpretation of CS within the organisations involved with the CSI)
Management of the trans-epistemic knowledge (communication, exchange of experience, knowledge sharing mechanisms, learning processes	Application and dissemination of the outputs of the CSI (new knowledge, products, solutions, etc.)	Normative layer (normative changes triggered within the organisations involved with the CSI)
		Operational layer (changes in practices, skills, tools, projects, and methods within the organisations involved with the CSI)

The model has been developed using different sources.

The first component (Transepistemic anchorage) is based on a simplified interpretation of the model developed by Probst (1998), of the building blocks of knowledge management. It was chosen since it allows the recognition of the many processes and obstacles characterising the identification, brokering, sharing, and actual exploitation of knowledge of different types where different groups are involved.

The second (Social anchorage) and the third component (Institutional anchorage) are both based on the model of institutional change developed by Kalpazidou Schmidt, & Cacace (2019).

These authors identify four key steps of the institutional changes, i.e.,

- The creation of the group of actors able to activate the change (corresponding in many cases to the CS project team)
- The mobilisation of the social actors (mobilisation of stakeholders)
- The friction of the actions implemented by these actors on the existing structures (contextualisation process)
- The actual change of existing structures (application and dissemination of the outputs of the CSI).

The same authors also distinguish four dimensions of the institutional change process which have been applied to the component of the institutional anchorage.

- The symbolic layer concerns the image of the proposed changes (in this case, changes in the way in which CS is perceived, in terms of visibility and relevance)
- The interpretive layer concerns the interpretation of the proposed changes (in this case, the interpretation of CS as an approach that can improve the quality of science and its impact)
- The normative layer concerns the introduction of new norms, in a broad sense (new organisational units, new regulations, new standards, new procedures, etc.) that allow the change to occur
- The operational layer concerns the actual implementation and diffusion of the proposed change (in this case, making CS a business-as-usual approach).

These models do not necessarily reflect how changes occur but provide useful coordinates for capturing the dynamics of change when they occur.

The three forms of anchorage are intertwined. The transepistemic anchorage is likely the most peculiar feature of CS, distinguishing it from other forms of citizens' participation and especially from other approaches to scientific knowledge production. If the knowledge produced by or with laypeople is not recognized, used, or properly managed, the epistemological impact of CS simply disappears.

However, a good transepistemic anchorage is possible only when citizen scientists, professional scientists, and their institutions work well together. Thus, the quality of social anchorage processes becomes pivotal. In turn, both forms of anchorage risk being not sustainable and scarcely impactful if the institutional anchorage process fails to occur, i.e., if organisational learning processes do not start.

Based on some preliminary findings of Step Change, some factors seem to hinder or slow down the activation of the cross-cutting level.

- CSI teams are more interested in and engaged with the analytical level rather than the cross-cutting one.
- It is not always easy to transfer to the CSI teams the concepts and the theoretical assumptions on which the cross-cutting level is based, even though the Evaluation Framework has been discussed and modified based on inputs from the same teams.
- The implementation of the cross-cutting level requires exchange mechanisms involving all the CSI teams, while this is not necessary for applying the analytical level.
- The cross-cutting level can be started only in a later stage of the development of the CSIs, entailing changes in already consolidated procedures.

However, there are some immediate potential benefits deriving from the application of the cross-cutting level.

- It becomes possible to distinguish in any CSI what is "fully local" and what is simply a "local variation" of recurring CS-related dynamics. This favours the teams in finding solutions already tested elsewhere.
- The cross-cutting level pushes CSI teams to go beyond their project to reflect on its long-term possible impacts on science practices and organisational changes at the local level.
- The cross-cutting level helps participants become more aware of the potential, limits, benefits, and risks of CS, thus overcoming simplistic views and stereotypes.

INTERACTION BETWEEN THE TWO LEVELS

The analytical level and the cross-cutting level are intertwined.

Most data are used twice, once for evaluating and supporting the individual CSI and once, in a different way, for identifying recurrent patterns and dynamics across the CSIs. In such a perspective, the cross-cutting level can be considered as a second-tier interpretation of the data and information produced under the analytical level.

The output of the cross-cutting level can help better understand the experience of each CSI at the analytical level, creating a sort of "feedback loop" between the two levels.

METHODOLOGICAL TOOLS

To activate and implement the evaluation framework, some methodological tools have been put in place. Since the evaluation process is still ongoing, only partial information can be given about the constraints met in applying it.

Firstly, five Local Evaluation Units – one for each CSI – have been established, made up of non-professional evaluators and stakeholders' representatives. In turn, each Local Evaluation Unit works in cooperation with a Central Evaluation Unit, made up of professional evaluators.

The Local Evaluation Units are established autonomously by the different CSI teams, involving professional and citizen scientists and, when possible, stakeholders. The unit members remain part of the CSI team and fully participate in its activities. However, they play an additional role, i.e., recording the most relevant facts occurring during the implementation of the CSI (for example, by filling in a diary) and elaborating their view about the development of the CSI, which are shared with the Central Evaluation Unit but especially with the rest of the team.

This organisational scheme has some advantages (ensuring the continuity of the evaluation process; ensuring a strong involvement of CSI teams throughout the project) but its application can also meet some obstacles.

- CSI teams include few people, thus identifying a sub-group of them specifically involved in the evaluation process can be problematic.
- CSI team members who are not part of the Local Evaluation Unit may feel marginalized.
- It is difficult to involve representatives of stakeholders in the evaluation process.
- The involvement of the Local Evaluation Unit in the application of both the analytical and the cross-cutting levels could be too demanding.
- Finally, a turnover of citizen scientists is highly probable (each CSI lasts around two years); and this could also affect the continuity of the evaluation work.

While at the analytical level the Central Evaluation Unit bilaterally interacts with each Local Evaluation Unit, at the cross-cutting level Local Evaluation Units and the Central Evaluation Unit work together as a single research team.

Secondly, a process of customisation of the Evaluation framework was carried out to adapt it to the specific features of each CSI and its context (normative context, policy context, research context, etc.). The principle is that evaluation can develop useful knowledge only if the causal power of context is recognised (Byrne, 2013), considering local factors and emerging dynamics (Kalpazidou Schmidt, & Cacace, 2017; Kalpazidou Schmidt, & Graversen, 2020).

The first step has been the organisation of five Customisation Workshops, one for each CSI. Every issue included in the analytical level has been scrutinised to identify their conditions of application, taking into consideration both the contents of the CSI and the context in which the CSI is developed. This exercise led to discarding the issues that turned out to be not relevant to the CSI and identifying those crucial for its development.

Other customisation initiatives are planned since some of the issues (for example, those about the impact) become relevant only in a later stage of the CSI.

Thirdly, following the tenets of developmental evaluation, the evaluation process is shaped as an iterative learning process including three steps: 1) collecting and documenting feedback on project implementation; 2) adopting "evaluative thinking" allowing to make sense of such feedback, and 3) developing a new understanding of situations to devise new measures addressing upcoming challenges (Kalpazidou Schmidt, & Bührer, 2020).

Three three-step evaluation cycles are organised throughout the project. Each cycle, lasting 4-6 months, includes:

- A two-month data collection phase (step 1)
- A monitoring meeting, involving the Local and the Central evaluation units, aimed at identifying critical issues and anticipating future bottlenecks or opportunities (step 2)
- Another two-month phase aimed at collecting information on the implementation of the CSI, especially for the critical issues identified in the monitoring meeting (steps 1 and 2)
- A larger monitoring session, involving the CSI team and relevant stakeholders, where the critical issues are reconsidered and, in case, new solutions are developed (step 3).

Starting from the second cycle, the collected information is also used for feeding the analysis at the cross-cutting level.

A set of templates (monitoring outlines, standardised minutes of each meeting, etc.) have been developed for each step. To collect first-hand information useful for the evaluation, interviews with stakeholders, policymakers, and other relevant actors are planned (15 interviews at least for each CSI during the second evaluation cycle). Moreover, specific items and topics are introduced in the tools already used in each CSI to get feedback, like workshops, living labs, focus groups, or community meetings.

The data processing is not confined to the end of the evaluation process. Rather, data are elaborated on during each evaluation cycle and interpreted in the three monitoring sessions. As for the analytical level, five Final Evaluation Workshops (one for each CSI) are planned where an overall assessment of the CSI will be co-developed by all the actors involved, based on a document jointly prepared by the Central and the Local evaluation units. As for the cross-cutting level, a preliminary document will be drafted by the Central Evaluation Unit and discussed with all the CSI teams.

The results of the evaluation process will be presented in the Final Evaluation Report (based on the collection of data at the analytical level) and will provide the basis for the development of a Model of R&I socialisation through CS (based on the collection of data at the cross-cutting level).

CONCLUSIONS

As highlighted above, Step Change is intended to both favour the development of effective CSIs in three key societal areas (energy, health, and environment) and explore the potential of CS to favour the shift to a new social model of science characterised by greater openness to society. The evaluation approach has been therefore developed with the aim to assess the CSIs in connection with both of these objectives.

While there is a wide stock of knowledge on how CS projects can be assessed and supported via evaluation, this latter has been rarely used to better understand the possible systemic impacts of CS projects on, e.g., research practices, the structure of research organisations, the scientific teaching programmes, the research funding schemes, or the use of research as a means to address complex social and technical issues on the part of stakeholders. The risk is to consider CS as a niche approach, useful only for responding to specific needs, but which has little to do with the core structures, methods, and practices of research systems and organizations.

The lack of a consolidated experience in the use of evaluation to study CS projects also for its systemic impacts represents a serious limitation and makes the evaluation exercise carried out in Step Change particularly uncertain, especially for what concerns the identification of the key aspects to put under observation and the adoption of effective tools assess them (assessing long-term processes is always problematic). The approach is currently being tested and only one out of three planned evaluation rounds has been started (the last one is planned for the end of 2023). It is therefore too early to assess its effectiveness and value.

Although these limitations and risks, Step Change raises a question that deserves to be deepened, i.e., how to observe CS projects not only in their immediate or expected results but also for the possible longer-term change processes they are able to trigger both within science and in the way in which science is used in society.

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THE VALUE OF VISUAL CO-ANALYSIS MODELS FOR AN INCLUSIVE CITIZEN SCIENCE APPROACH

ACADEMIC MANUSCRIPT

INSPIRED BY CO-CREATION METHODS FROM DESIGN THINKING

CATHARINA VAN DEN DRIESCHE AND SARAH KERKLAAN

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ABSTRACT

Citizen science entails the collaboration of citizens and scientists. The process of this collaboration can take on many forms: identifying a research question, collecting data, analysing data to support or refute a hypothesis, monitoring environmental or health conditions for management or policy development. Citizen science propagates the inclusion of citizens not only as participants engaged in the design research process but also involved in designing the research process itself. In order to address issues of a citizen science approach, it is important that potentially everyone can contribute. Therefore, methodologies need to be fine-tuned to improve the involvement of non-professional researchers in the research process. Co-creation methods may be an effective methodology for doing so and bring different types of knowledge (e.g., insights, experiences, data, information) to the 'table of science' and, ultimately, improve the constructive exchange and evaluation of this knowledge.

This article describes the process of a pilot where professional researchers, informal caregivers, and human resource advisors use visual co-analysis to create a research plan. For the framing of this research a theme was proposed which focused on the possibility of technological support for work-related challenges experienced by informal caregivers working in healthcare. Five semi-structured interviews were conducted by researchers with informal caregiver in the first phase of 'Empathize' within design thinking (i.e., human centred approach). The goal of the interviews was to understand and relate to the caregiver's perception of their current informal care situation (e.g., balance, bottlenecks, opportunities, well-being). Quotes selected from theses interviews were the input for a bottom-up methodology for citizen science using the KJ Method (i.e., affinity diagramming) as a form of visual analysis model. The (co-)analysis was done by the team of caregivers, HR advisors and researchers using the online tool Miro.

This article aims to describe how the use of visual analysis models as a group consensus technique can facilitate the involvement of non-professional researchers and thereby support the establishment of inclusiveness of a citizen science approach. In other words, to obtain equal collaboration, an inclusive citizen science approach must allow communication about, and analysis of data by all participants, instead of non-professional researchers merely being presented with the finalized results of the analysis phase within research. An inclusive citizen science approach might lead to a period of uncertainty where problem definitions, research questions or predefined categories posed early on are (re-)assessed. However, this bottom-up approach will ultimately lead to a positive impact in finding the root problem for innovative scientific outcomes. Together, the pilot study and descriptive review offer guidance for understanding visual co-analysis models as the starting point for an inclusive citizen science approach.

1. INTRODUCTION

Citizen Science is an evolving approach in science moving from engagement with citizens to involvement in the research process by citizens (Bonney et al. 2009). It is in this recent development of collaborative partnerschip that design research, as an iterative and participatory process, is attracting increasing interest as an enabling factor for citizens to be involved in designing the research process. To enable citizens involvement in the design of the research process there is a need to go beyond the contributory approach to achieve equal collaboration using different types of knowledge. Therefore, communication about data implies being able to (co-)analyse data instead of only being informed (Vaughn & Jacquez 2020) in an inclusive citizen science approach.

The collaborative nature of citizen science especially challenges the initial phase in the design research process. Since different stakeholders coming together have probably already experienced and obtained knowledge for the issue at hand. Hence, to accomplish inclusiveness in citizen science, the exchange of experiences, knowledge, questions, and insights must happen in a way that permits communication about this data for (re-)formulation of the problem. This communication about data is a critical factor when addressing increasing complex problems that are in need of a scientific solution. Therefore, the collaborative partnership of an inclusive citizen science approach needs new insights on 'stretching' existing (design) methods for the production of knowledge (Hecker 2019).

In a pilot on informal caregiving, an onboarding process (i.e., becoming and staying involved in the research process) was developed to conduct citizen science in a way that meets the previous noted considerations. The first condition for onboarding in an inclusive citizen science approach is to (co-)create open and dynamic entry points during every phase of the research process. The second condition is to share knowledge, information, or insights from all participants at the start of the onboarding process for evaluation and collaboration purposes. Third, to support working together in a way suited for and agreed upon by all participants towards collaboration on an equal basis. An important factor for these three conditions is being able to decide on what role to take on. These roles vary from being informed, consultant, partnership, collaborator, or role of empowerment in leading the research (Vaughn & Jacquez 2020).

For the support of onboarding the research study described in this paper questioned if and how visual analytic models (VAM), imbedded in a co-creation process, can inform the design of the research question, and the research process itself (i.e., inclusiveness in citizen science). Because the use of VAM improves knowledge and insights (Keim et al. 2008) and therefore stimulates the valuable evaluation, selection, and transparent development of the design research process. The KJ Method (i.e., affinity diagramming) developed by Jira Kawakita (Sugiyama & Meyer 2008) was chosen as a visual analysis model imbedded in a co-creation set-up to define the research problem.

Together, the KJ Method theory and the descriptive review of the pilot offers guidance for understanding the value of VAM for the starting conditions of a citizen science approach on two levels: the co-creation of knowledge by interacting with an affinity diagram and the 'on-going' learning process about the research process itself. Although citizen science allows for multiple roles for non-professional researchers, in this article the focus is on the 'empower level' of participation (Vaughn & Jacquez 2020) in which non-professional researchers and professional researchers share decision making in each stage of a research process.

2. BACKGROUND ON VISUAL ANALYTIC MODELS

In the early nineties designers adopted qualitative methods from anthropology to validate design decisions using data mostly from observing and interviewing users or customers. These qualitative methods are used in design approaches (e.g., contextual inquiry (Beyer & Holtzblatt 1998), service design (Stickdorn & Schneider 2014) and design thinking (Dorst 2011)), which give designers insights into (long-term) user or customer experiences. By visually mapping the user or customer experiences into models and seeing how these experiences are connected give designers the tools and techniques to validate design decisions. Additionally, in the design process itself an effect was noticeable of an increasing emphasis and time placed on finding the root problem due to visually accessible data for all stakeholders. Another effect of mapping user data into visual models is the support of conversations amongst designers, users, and clients.

A shift in VAM development came about when visualized models were adopted into co-creation processes using VAM as so-called work models (Beyer & Holtzblatt 1998). During co-creation sessions of categorization of data in a bottom-up way, participants were guided by the models in 'seeing' ideas for innovative solutions. Interacting with visual models created a 'visualized knowledge process' (i.e., inquire knowledge), enabling people from different backgrounds to speak and learn about data (Keim et al. 2008). It is this visualized knowledge process of sharing and structuring data into comprehensive understanding (i.e., awareness) that provides the foundation for synergy of knowledge (Kastner et al. 2012).

In this article it will be argued that the KJ Method (i.e., affinity diagramming) developed by Kawakita in 1975 (Sugiyama 2008) supports an inclusive citizen science approach. The KJ Method is a bottom-up approach for the exchange of data and evaluation of knowledge as a visualized knowledge process as well as a knowledge synthesis method (Kastner et al. 2012). The overall goal of this method is to synthesize experiences, information, and (scientific) knowledge to obtain valuable insights into solving complex problems. To allow a deeper insight into the KJ Method, the research approach will be placed in visual analytic research (Keim et al. 2008) and set up from the perspective of visualization research as a scientific discipline (van Wijk 2006).

To support finding the problem statement two design processes were integrated : the double diamond design process (Norman 2013) in combination with the design thinking phases of Understand, Empathize, Define, Prototype, and Validate (Dorst 2011) (Figure 2).

2.1 KJ METHOD: EXCHANGE OF DATA FOR FORMULATION OF THE PROBLEM

The design research process traditionally starts with an exploration phase where inquiry into the context of a problem is iteratively defined. In the basic scientific approach of Kawakita's W-shaped model (Scupin 1997 p. 235), understanding a problem occurs at two levels: experience and thought (Figure 1).

For the formulation of the problem, point C to D in the model, Kawakita created an analytic mapping tool to combine different types of knowledge based on experience and thought. In design research this analytic mapping tool is also known as an affinity diagram (Scupin 1997). This method is based on bottom-up and intuitive (i.e., not learned) labelling of different kind of data (e.g., interview quotes, observation notes, photographs) by multiple stakeholder groups. Kawakita defines four steps for affinity diagramming: (1) Label making, (2) Label grouping and title making, (3) Special arrangement and chart making, and (4) Verbal or written explanation. Affinity diagramming was developed to connect unorganized data for the purpose of universal applicability of interpretation, as Kawakita states:

> *"... the practice of the KJ Method has given a great number of people a new lease on life and rejuvenescence of their energies, generating at the same time true personal contact and creative consensus among people who practiced the method together"* (1977:97). He [Kawakita] emphasizes that the KJ Method enables people to free themselves from a priori assumptions, preconceived notions, rigid formalisms and dogmas, or unrealistic hopes or utopianism. Kawakita claims that the KJ Method assures scientific treatment of qualitative data, resulting in realistic, objective conclusions (1991:15). (Kawakita 1977, as cited in Scupin 1997)

Although Kawakita's idea of universal applicability (i.e., group harmony or consensus) is rooted in the Japanese culture of "decentralization of decision-making as a quality control method" (Scupin 1997), in citizen science it can uphold inclusiveness for 'low entry onboarding'. First, by being able to 'see' ideas in VAM, the decision to be involved in citizen science can be validated early on. In other words, VAM supports the discovery of the value of collaboration. Second, participants can then

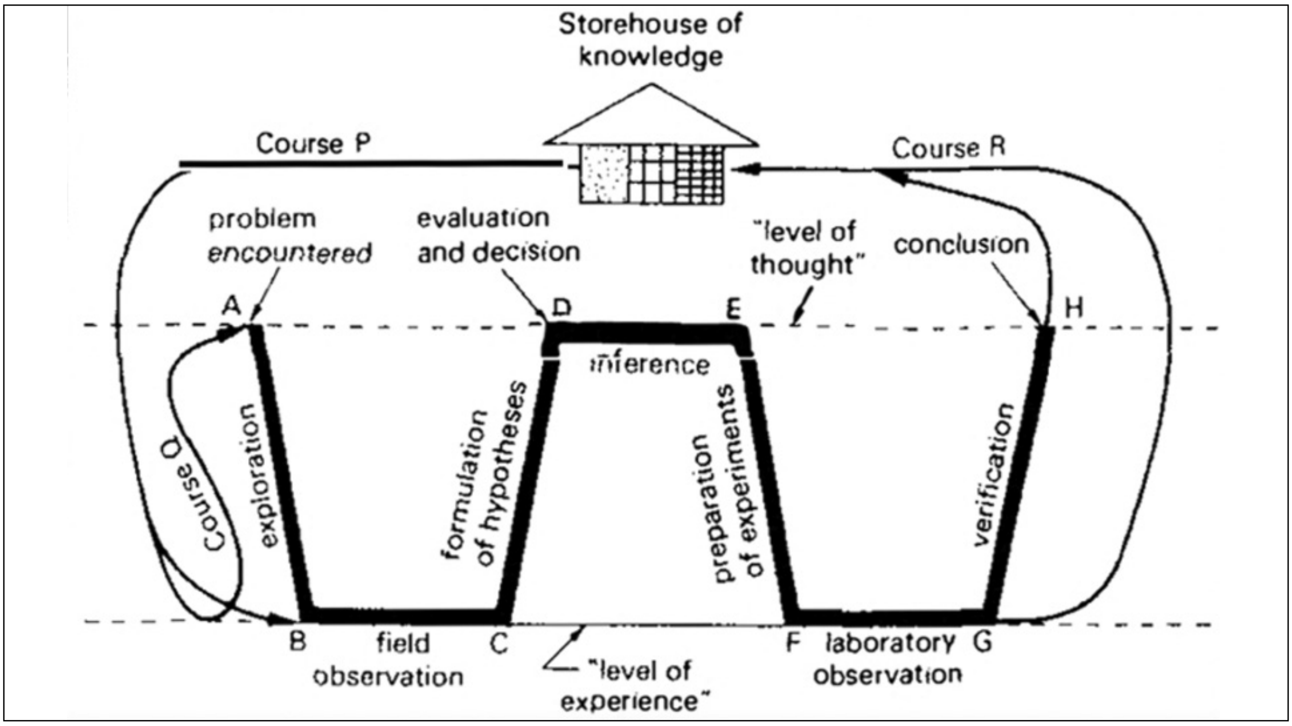

Fig.1: Kawakita's W-shaped model (Kawakita 1977, reproduced from' Scupin 1997) (p. 235)

decide on their role for (co-)designing the research process, starting with (re-)defining the problem. Third, by sharing of VAM citizens can stay informed or be involved again without experiencing a disadvantage. In this way the value of visual models in facilitating collaboration on an equal basis has a double effect: it transforms knowledge about data to the level of thought and evaluations of the design research process itself (Keim et al. 2008).

2.2 CREATIVE ABDUCTION FOR EVALUATION OF DATA TOWARDS PROBLEM FINDING

The foundation of the KJ Method as Kawakita developed it, is Charles Peirce's concept of creative abduction (Anderson 1986). Creative abductive reasoning is based on the combination of intuition and analytic interpretation of data. This creative search strategy (Schurz 2020) func-

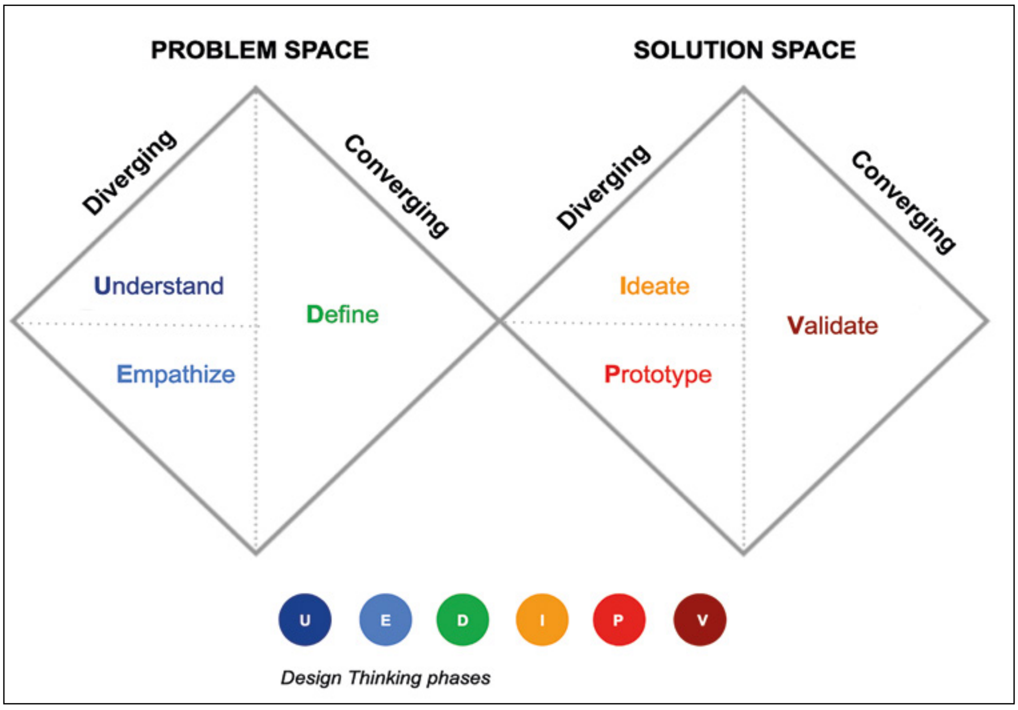

Fig.2: Double Diamond using the Design Thinking phases. Adopted from Norman, 2013 (p. 220)

tions as an intuitive non-logical thinking process or as "a meta-scientific form of reasoning" (Scupin 1997) which conforms logical reasoning from observations (i.e., what makes sense based on what we see) to select the most likely hypothesis. In citizen science projects initiated by professional researchers the research plan might already be defined before citizen are approached (i.e., problem definitions posed early on). Hence, the deployment of an inclusive citizen science approach might lead to a period of uncertainty wherein research plans are re-assessed.

An abductive reasoning as a creative search strategy (Schurz 2020) can provide direction for the 'chaos' of redefining the research plan in citizen science. Abductive reasoning is part of the first cycle of the double diamond design process (Norman 2013) of problem finding (i.e., process of diverging) (Figure 2). This process of diverging and converging supports the re-opening of the problem statement towards evaluation of quality and value for a scientific hypothesis. During the second cycle in the problem space (i.e., process of converging) the 'proof of problem' takes place by embedding measurements (e.g., empirical testing, case studies, scenarios, role play, sets of small experiments, online analytics) for the definition of a hypothesis.

Abductive reasoning supported by affinity diagramming creates an evaluative explanation of data through collaborative structuring that forces change or improvement of pre-defined problem definition or research question. The downside is that in abductive reasoning, in contrast to induction, there are no consistent results, making it almost impossible to detect an 'error' before the last phase of Validate in the design process. To avoid this problem an iterative testing in all phases would be necessary.

In the fourth step of the KJ Method (i.e., verbal, or written explanation) the provisional problem statement can be discussed using the affinity diagram. The explanation will differentiate between descriptions (i.e., visualized arrangement) and interpretations (Scupin 1997) that create new knowledge for understanding the root of the problem. Using an affinity diagram in iterative loops makes it possible to go back to the visualized arrangement during discussions for finding a problem statement to ultimately (co-)design the research plan.

To further explore whether using VAM within a co-creation process facilitates an open process structure in an inclusive citizen science approach an affinity diagram was used in the pilot on caregiving. The pilot focused on informal caregivers working in health care balancing tasks in their personal life and work situation. In this pilot two components of the onboarding conditions of citizen science were integrated: 1) working on an equal basis for collaboration with professional and non-professional researchers and 2) using VAM for (co-)analysis of five semi-structured interviews held by professional researchers with informal caregivers who were also participants in the (co-)analysis sessions.

3. METHODOLOGY

One of the pilots of the project TOPFIT Citizenlab[1] focuses on the theme of informal caregiving. The first research goal of this pilot was to create a technological innovation to pre-emptively improve the sustainable employment of informal caregivers working in health care. To lay the groundwork for an equal collaboration the research process was based on the phases in design thinking (i.e., human centred approach) (Dorst 2011). The second research goal was to explore an inclusive citizen science approach using the ten principles of citizen science according to the European Citizen Science Association (ECSA) (Hecker et al. 2018). The two research goals are ideally accomplished by co-creating the research plan in an equal collaboration between all participants of the pilot. The team existed of three groups:

1) Four [4] Citizenlab researchers, with a background in design research, physiotherapy/healthcare, wellbeing at the workplace and valorisation.
2) Six [6] informal caregivers working as professionals in healthcare while at the same time taking care of their partner, family member, or friend.
3) HR group of six [6] people existing of five [5] Human Research managers and one [1] Informal Care Advisor.

The caregivers pilot started in 2020 with an online questionnaire and five semi-structured interviews conducted by researchers with informal caregivers. The overall question for the interviews was centred on how caregivers experience daily life and work. The pilot is ongoing and will continue until December 2022 with some options for continuation. To be able to demonstrate whether VAM can function as an open process structure in an inclusive citizen science approach this article will focus mainly on the second session of analysing interviews using affinity diagramming (Figure 3).

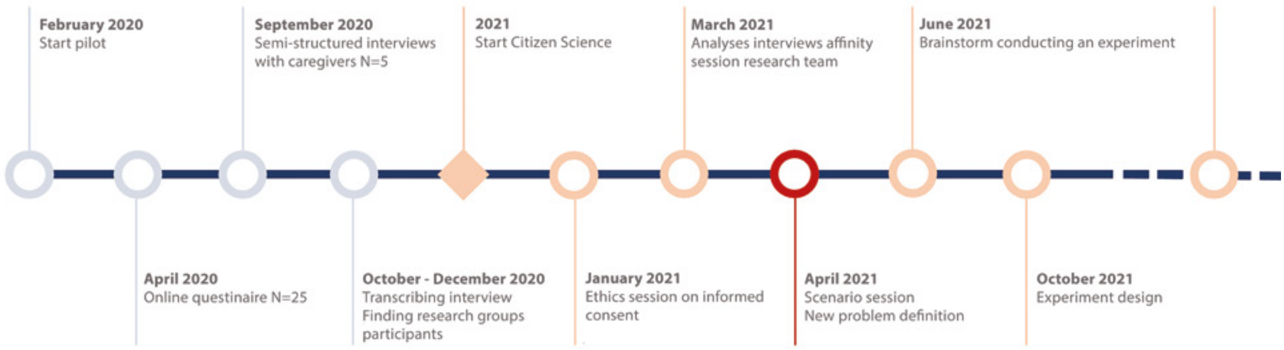

Fig.3: Overview of the process of the Citizen Science approach. The pilot will run until December 2022 with some options for continuation.

1 TOPFIT Citizenlab 2020-2023. TOPFIT Citizenlab is a three-year research and innovation programme based in Twente in which citizens, healthcare professionals and companies join forces with researchers to develop and implement technological innovation for health and healthcare. The educational institutions that are involved are University of Twente, Saxion University of Applied Sciences and ROC Twente, the Netherlands.

As mentioned, an affinity diagram is a visualization model of any kind of data as a purely bottom- up approach (Beyer & Holtzblatt 1998). In design research it is mostly used for categorizing quotes from qualitative interviews (Scupin 1997). The initial reasons and goals for using the affinity diagramming for (co-)analysis in the pilot were:

1) Sharing existing knowledge and experiences (bottom-up) of informal caregivers through scalable visualization.
2) Learning 'on the go' of research skills and how to work together using co-creation methodologies.
3) A broader insight into knowledge and experiences on caregiving in general that will give caregivers the tools to come up with solutions for challenges in the daily lives of other caregivers.
4) Gaining insights for agreements about the next step in the research process.

3.1 APPROACH

An explorative approach was taken on towards learning about a citizen science process by discussing every step in the process by the research team. The activity of affinity diagramming differed from the conventional KJ method in mainly two ways: first, the reviewing by interviewees of their own quotes and second, in the creation of three diagrams by each group in stead of one (Table 1). The three diagrams were used for comparison and discussion of different and overlapping perspectives on experiences, root of the problem and ideas for solutions.

KJ Method/Affinity	Affinity diagram in Citizen Science approach
(1) Label making. (2) Label grouping and title making. (3) Special arrangement and chart making. (4) Verbal or written explanation.	(1) Review of quotes by interviewees who were also part of the pilot research team. (2) Label making. (3) Label grouping and title making. (4) Comparison and discussion of the three diagrams.

Table 1: Overview of the steps of the conventional KJ Method and steps used in the Citizen Science approach for the pilot on caregiving.

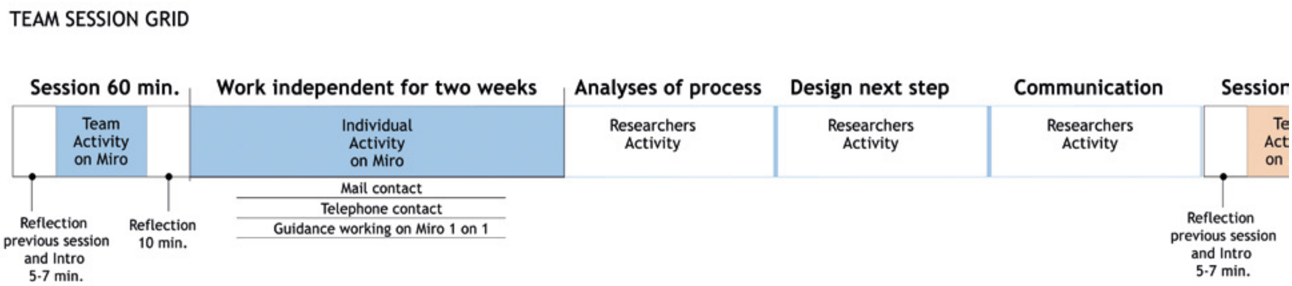

Fig. 4: Team Session Grid. The team exists of informal caregivers, HR advisors and researchers.

The Team Session Grid (Figure 4) shows an overview of the general set up of a team session based on proximately a year of working together in the pilot. The three Researchers Activities took about 4 to 6 weeks to complete.

The analysis of the process was discussed as a team in the Reflection parts, at the beginning and end of the session. During these reflections everybody talked about the approach and methods (e.g., time, working in Miro, content/quotes, observations, roles, alternative methods) used in the session. The outcome of these reflections made it tangible to understand what support everybody needed to (co-)create a framework for staying involved. The researchers remained facilitators of all the sessions because the caregivers and HR groups preferred it that way, mainly because of lack of time. All reflections were noted by the researchers and shared via e-mail. The planning of the next co-creation session was either discussed at the end of the session or by using an online date selection tool.

3.1.1 CODING INTERVIEWS FOR AFFINITY DIAGRAMMING

For the coding of the interviews the categorization of the mental model approach by Indi Young (Young 2008) was used. This mental model approach (Young 2008) provides three categorizations that focus on how people are currently handling certain challenges in daily life: Emotions, Behaviour, and Philosophy (i.e., how people ideally want to handle their challenges). The focus of the semi-structured interviews was based on the question what caregivers experience in daily life taking care of others and working in health care (i.e., being a professional trained health caregiver and extend these skills into personal life). After researchers coded and anonymized the interview data, the coding process was explained to the interviewees. Every interviewee was given the opportunity to refuse privacy-sensitive quotes in the context of the GDPR and from an ethical point of view. They were also encouraged to add quotes that weren't included by the researchers. None of the interviewees added or refused quotes. For the informal caregivers who were interviewed an additional consent for usage of the selected quotes in the co-creation sessions was added.

3.1.2. ANALYSES USING AFFINITY DIAGRAMMING

Learning about each other's perspectives is a key component of onboarding and equal collaboration towards collaborative partnership. To ensure that every group could share their perspective from personal experience and knowledge each group created an affinity diagram. The researchers created their affinity diagram after the affinity session so they could assist working with Miro during the session. An affinity diagram template (Figure 5 and 6) was set up in Miro that remained available for two weeks after the one-hour online session. The total of 295 quotes of the five interviews were placed on Miro sticky notes and shuffled for each group. Next, the quotes were randomly divided amongst the participants of each group. Each participant was given about 60-73 quotes, depending on the groups size, which were placed underneath their name.

Fig. 5: Miro setup of the affinity diagram for informal caregivers, HR advisors and researchers. Moving quotes into groups and labelling the groups.

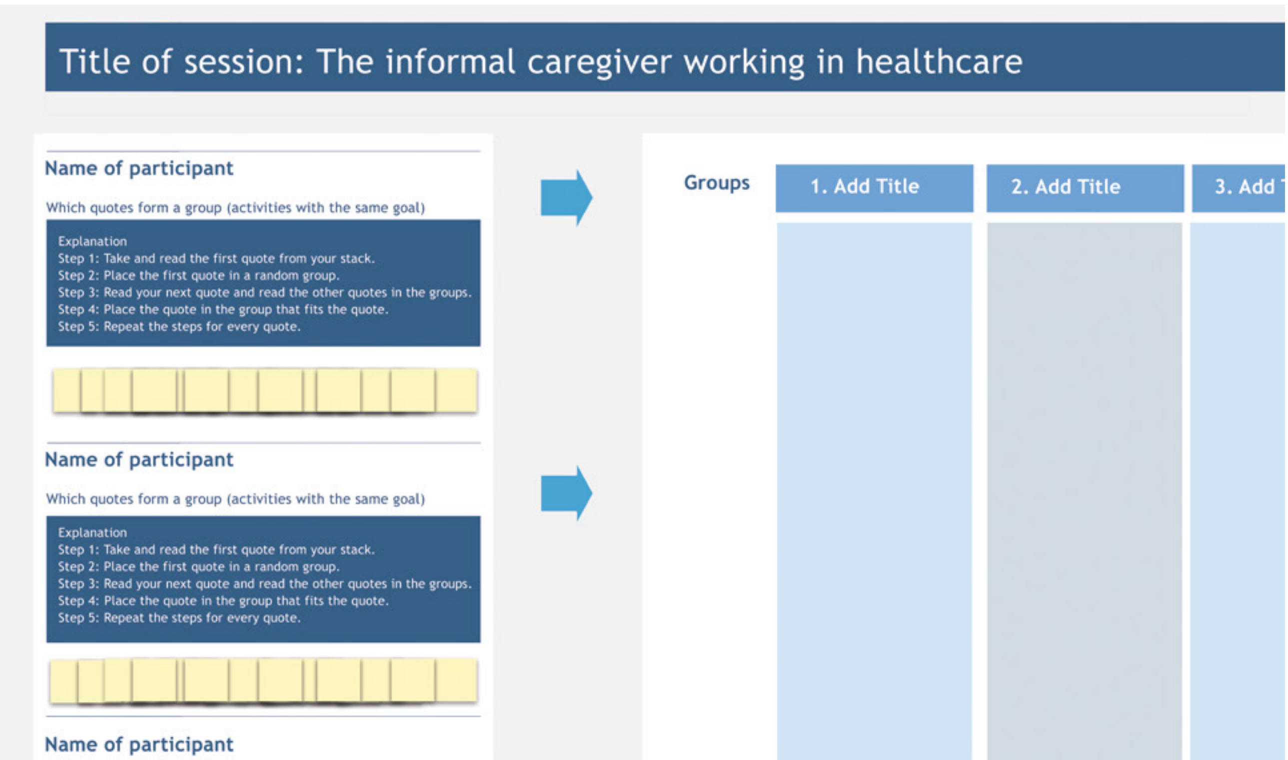

Fig. 6: Miro setup of the affinity diagram for informal caregivers, HR advisors and researchers. Moving quotes into groups and labelling the groups.

At the beginning of the affinity session the model was explained during the introduction part using Microsoft Teams. The creation of the affinity diagram happened in five steps (Figure 6):

1) Take and read the first quote from your stack.
2) Place the first quote in a random group.
3) Read your next quote and read the other quotes in the group.
4) Place the quote in the group that fits the quote.
5) Repeat the steps for every quote.

To clarification on intuitive grouping was as follows: 'Which quotes form a group (activities with the same goal)' (Figure 6). Creating the affinity diagram happened in silence because some people are verbally stronger than others, therefore preventing an imbalance in working together.

At the end of the session there was a reflection on the method of affinity diagramming and the next steps were discussed. The researchers, as facilitators, asked who was planning to use the Miro template of the affinity diagram in the next two weeks after the co-creation session and who wanted support. Most of the participants used the Miro template after the session. Two of the participants asked for support and researchers provided a one-on-one session for both.

Fig. 7: Affinity diagram by informal caregivers (anonymized screenshot of the Miro board).

3. 1. 3 NEXT STEP IN THE PROCESS: SCENARIO SESSION

After creating and discussing the affinity diagrams every group selected the three most important categories (i.e., group labels) in the next online session (Table 2). Some of the categories were merged because they were considered inseparable.

	Caregivers	HR advisors	Researchers
Categories Top 3	1. Collaborate and communicate 2. Setting Boundaries/ Relaxing 3. Work (job)/Organize	1. Clarify need 2. Communication with all involved 3. Taking care of yourself/Personal development	1. Forget about yourself / Just carry on / Stress from caregiver 2. Support by care organization/ Municipality/ Employer 3. Participation control by informal caregiver and relative / Loss of autonomy

Table 2: Selection of Top 3 categories (i.e., group labels) by each group.

By selecting the most important categories in the diagram new insights were gained for finding the root of the problem. The three categories of one group were given to another group (i.e., Round Robin technique) to create a context scenario. In this scenario the context of the categories is described obtaining the root of the problem, actors, possible support, needs and roadblocks. After discussing the three scenarios the whole team created one shared context scenario that would be the blueprint for defining the problem statement.

Scenario Session, after the affinity diagramming session.
1. Selection of three categories in need of (technical) support. 2. Round Robin technique: each group created a scenario that would support the categories selected by another group. 3. Discussing the three scenarios. 4. Creating one shared scenario as a team.

Table 3: Overview of the steps in the Scenario Session.

Following the scenario session all participants were asked to fill out a small questionnaire (Table 4 and 5). This questionnaire consisted of three questions about the experiences of the approach: motivation during the meetings, increase in knowledge (content and approach), and motivation for future meetings. Answering the questions involved selecting an option of the Likert: none-low-middle-high-very high. The questionnaire ended with an open field for improvements and positive feedback.

Overall results	
Motivation	middle-high
Knowledge increase	middle
Future motivation	middle-high

Table 4: Overall results of the whole team

Improvements	**Positive feedback**
Having face to face meetings.	Respect for each other's experiences in the conversations. Curious what may come out in the end because everyone experiences informal care in their own way.
Groups are too small.	Learning to work with the method and working with different disciplines.
Insufficient depth due to too short meetings.	Clear meetings, clear what is expected of you.

Table 5: Aggregated outcomes of the whole team for Improvements and Positive feedback.

3.3 SUMMARY OF THE MAIN FINDINGS

All findings are based upon the notes taken during the online 60-minute sessions, the notes of communication between online sessions (e.g., telephone and e-mail) and the questionnaire shared after the scenario session (Table 4 and 5).

Co-analysis of data in a co-creation setting created awareness of the context from multiple perspectives while working with different disciplines (i.e., transdisciplinary) (Wright et al. 2015) toward defining a problem statement and ultimately a research plan. Some team members shared negative experiences on having cooperated in research projects before and being left with a feeling of "…but nothing changed for me". Hence, although affinity diagramming was new to the participants, the idea of defining the research question and creating the research plan gave them a feeling of being actively involved in the research (i.e., empowered). Being and feeling involved in a citizen science approach assisted an active communicating of expectations for doing research activities together.

The grouping of the quotes happened in a smooth way without any informal training. Several participants worked independently with the Miro template during breaks at their job, the only moment they had spare time. Although working online was a steep learning curve in the beginning, it turned out to be crucial for the participants to stay involved. Mostly valued in the affinity diagramming was the ability to learn about each other's perspectives and still be able to visualize and value individual perspectives. Affinity diagramming made it possible to get started on analysing the data during the first session keeping the period of uncertainty of problem finding to a minimum.

As for professional researchers and for human resource advisors, setting up an affinity diagram gave insights into the 'other' (i.e., the informal caregiver). On the other hand, for the individual informal caregiver, labelling data from interviews triggered conscious thoughts about dealing with daily life that had become second nature for them. As well as this, it created an overview of many experiences and perspectives of how to deal with being a caregiver, taking a step back from a personal point of view to an overall perspective (i.e., moving from one too many). Within a short time span the affinity diagramming guided the evaluation of all the knowledge and insights from the interviews. This guidance through VAM supported staying close to the data for identifying the assumptions by separating descriptions from interpretations. For several participants, this led to a new position towards the problem situation without losing sight of personal needs and wishes.

Learning analytic research via VAM in a co-creation setting showed that seeing what others do prevents non-professional researchers from feeling embarrassed and uncomfortable (Cooper 1999). Furthermore, to work in silence during affinity diagramming was much appreciated. One participant mentioned dreading ongoing discussions about the different perspectives, leading to endless talking and no consensus or solution. Comparing the affinity diagrams by selecting the top three of most important categories supported a bottom-up way of researching challenges in informal caregiving. During the discussions about the categorization of the quotes and the selection of a top three, a mutual understanding of root pitfalls for solutions emerged. Hence, the interaction with an affinity diagram facilitated common grounds for collaborative partnership towards problem solving and decision making. In other words, the bottom-up approach of VAM enabled a movement from inclusiveness to sustainable collaboration in citizen science.

VAM added significant value to an inclusive citizen science approach in essential communication through the data. Communication through the data not only succeeded in reaching a common understanding for equal collaboration (i.e., the research process) but also an agreement on the problem statement towards a research question for finding an innovative solution. Consequently, VAM simultaneously created knowledge about the theme of informal caregiving as well as the research process itself and therefore it can uphold inclusiveness as 'low entry onboarding'.

4. CONCLUDING REMARKS

As mentioned before, the challenge of inclusiveness in citizen science lays in supporting onboarding, collaboration on an equal basis, and synergy of knowledge. The result and value of an inclusive citizen science approach stems from creative ways to stay involved. Especially because non-professional researchers aren't always able to or want to be involved. The use of affinity diagramming not only supports evaluation of data for (re)defining the research problem, but also supports an effective involvement during different phases of the process. And in doing so gaining new insights through co-creation methodology without any informal training.

Visual analytic research within a co-creation process supported an accessible way to synthesize different perspectives. During the caregivers pilot the participants: informal caregivers, HR advisors, and researchers, experienced improvement of empowerment through involvement in the research activities. The exchange of experiences with others, in the research project and in daily life or at work, created a mindset for thinking about the process. This approach for inclusion in citizen science takes more time, but trust, equal collaboration, and reciprocity lies in openness, transparency, and critical reflection of decisions made during the research process. The fluidness of this way of co-creative partnership showed an intrinsically circular knowledges process because it expands the context of research activities regarding new availability of research resources (e.g., skills, knowledge, tools) in society.

Nevertheless, more research needs to be done on VAM for an inclusive citizen science approach (e.g., comparisons of different citizens science projects, the influence of doing online research, issues in different domains, professional researchers onboarding in citizens research activities, citizens as facilitators) to validate that research outcomes are more successful in an inclusive citizen science approach. Therefore, inclusive methods like diagramming need to be fine-tuned for an inclusive citizen science approach. In other words, how conscious creation of knowledge about the collaboration process itself can be integrated into the research process. All in all, this indicates a need indicates a need to further enhance an understanding of a citizen science approach by using visual analysis models as an inclusive method for the co-creations of research questions and plans.

The caregivers pilot research team is still strongly motivated to stay involved and gradually new participants are added to the team.

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KEYWORDS: citizen science, evaluation, social models of science, late modernity, responsible research.

THE 'PAYBACK' OF CITIZEN SCIENCE
A PARTICIPATORY EVALUATION AND IMPACT-ASSESSMENT MODEL FOR SOCIAL INNOVATION PROJECTS

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ACADEMIC MANUSCRIPT

ABSTRACT

Citizen science projects for social innovation present solutions to society's complex challenges (da Silva et al. 2019). However, evaluating their impact is challenging (Bornmann 2012); an integrative impact-assessment framework considering all innovation process steps and impact dimensions while accounting for all participants' perspectives does not yet exist (Smit and Hessels 2021). One frequently used framework to evaluate impact beyond the academic sector is the Payback Framework proposed by Buxton and Hanney (1996). In its current specification, this framework does not apply to participatory projects due to its unilateral scientific perspective. This study applied the theory adaptation approach (Jaakkola 2020) to extend the Payback Framework's scope by informing it with the lens of another conceptual approach, namely the Service-Dominant logic. The study aimed to adapt the Payback Framework for citizen science projects, creating a Citizen Science Payback Framework. The new framework was created by adding the degree of external participation as a third component. The new component captures citizen participation and thus indicates the involvement of citizens in the evaluation process.

INTRODUCTION

Social innovations, which are defined as "novel solutions for social problems (…)" (Phills et al. 2008, p. 38), promise to overcome today's diverse social challenges (Pol and Ville 2009), including poverty, inequality, and the ageing population. A popular approach to social innovation is citizen science, the "participation of citizens in scientific processes" (Bonn et al. 2016 p. 13). This is the case because the involvement of citizens presents a relevant resource for improving the processes of research and innovation (Senabre Hidalgo et al. 2021). Citizen science can be described as an innovative way to develop and foster social innovation (Butkevičienė et al. 2021). The "collaborative generation of knowledge by academics working alongside stakeholder from other sectors" (Greenhalgh et al. 2016, p. 393) is usually called co-creation and is widely believed to increase research impact (Greenhalgh et al. 2016). Citizen science projects show a high diversity regarding the degree of participation (Schaefer and Kieslinger 2016), whereas the project outcomes and thus the impact is influenced by the degree of citizen participation during the project process (Shirk et al. 2012).

Over the past decades, various methods for evaluating research impact were generated when impact is defined as the effect research generates beyond building academic knowledge, including benefits for society, culture, and economy (Bornmann 2012; Spaapen and van Drooge 2011). However, most of the models only consider the academic perspective in the evaluation process, although a participatory evaluation complies to the normative aspect regarding democratic inclusion of multiple perspectives and the pragmatic justification that enhanced participation leads to better results (Springett 2017). While stakeholder participation is recognised as a relevant component of the evaluation, particularly impact evaluation, it remains theoretically and conceptually underdeveloped (Smit and Hessels 2021; Springett 2017).

Contributing to this gap, the theory-adaption approach (Jaakkola 2020) was used to expand the application domain of the Payback Framework, which is the most widely used and adapted model and the best approach to assess the impact of research projects beyond academic impact (Bornmann 2013; Donovan 2011; Penfield et al. 2014), to citizen science. This is done by applying the Service-Dominant logic (S-D logic) (Vargo and Lusch 2004) as a new lens to create an evaluation framework for citizen science social innovation projects. This Citizen Science Payback Framework considers the collaborative process of knowledge generation in the evaluation process by adding a new component that evaluates the citizen participation at each project step and indicates upon this the inclusion of the citizens in the evaluation process.

The remainder of this paper is organised as follows. First, it introduces the theoretical background on citizen science as an area of application, the Payback Framework as a potential impact-assessment framework, and S-D logic as a new perspective to bridge the gaps between citizen science and the Payback Framework. Subsequently, the theory-adaptation approach is described briefly and applied. From this, a Citizen Science Payback Framework (CSP Framework) based on the Payback Framework and enriched by S-D logic is presented and advocated. Finally, the theoretical and practical implications of the proposed model are discussed in detail; limitations and future research avenues are also highlighted.

CITIZEN SCIENCE

Citizen science can be defined as "the participation in scientific processes of people who are not institutionally involved with a specific field of science" (Bonn et al. 2016, p. 13). This definition of citizen science is generally accepted, but the degree of citizen involvement varies. For some academics, the term means public participation in scientific research; these scholars understand partnerships between citizens and scientists to be opportunities to create and handle large datasets. For others, citizen science is a move toward a scientific democracy in which citizens and scientists engage as equal partners in research projects (Bonney et al. 2016).

One approach to differentiating among citizen science projects focuses on the power and control of the different actors in the research process (Bonney et al. 2009). Bonney et al. (2009) established three models for public participation, viewed as three stages with increasing power allocated to citizens. The first stage entails contributory projects, i.e., projects designed by scientists in which citizens contribute data primarily. The second stage presents collaborative projects, which, in addition to the responsibilities of contributory projects, also allow citizens to assist in specific research steps. Finally, the third stage comprises co-created projects, designed jointly by scientists and citizens, in which citizens participate in most, ideally all, project steps (Bonney et al. 2009). Bonn et al. (2016) extended this differentiation by adding another (base) stage, in which citizens are passive observers whose sole contributions, if any, are to communicate ideas.

PAYBACK FRAMEWORK

Over the past few decades, many evaluation methods have been developed to capture the social impact of research (Smit and Hessels 2021). These evaluation methods differ in their assumptions of, e.g. actor roles, interaction mechanisms, concept of societal value and their understanding of the relationship of societal and scientific value (Smit and Hessels 2021). A few of the most notable models are, for example, the Social Impact Assessment Methods for research and funding instruments through the study of Productive Interactions (SIAMPI), the Australian Research Quality Framework (RQF), and the Payback Framework (Penfield et al. 2014).

The Payback Framework is one of the most commonly used methods to assess the impact of research projects beyond academic impact and was developed by Buxton and Hanney in 1996 in the field of health (Greenhalgh, Raftery, Hanney and Glover 2016; Milat, Bauman and Redman 2015). Since its creation, the Payback Framework has been applied multiple times and adapted and used in areas other than health services, including social sciences (Klautzer et al. 2011) and arts and humanities (Levitt et al. 2010). It was adopted by institutions such as the Canadian Institute of Health Research, the Dutch Public Health Authority, the Australian National Health and Medical Research Council, and the Welfare Bureau in Hong Kong (Penfield et al. 2014). Furthermore, the Payback Framework functioned many times as the basis or inspiration for other evaluation methods like the Contribution Mapping and the Impact Narratives, which presents one part of the Research Evaluation Framework (REF) for U.K. higher education institutions (Smit and Hessels 2021).

The reasons for the framework's popularity are numerous. The underlying theory of the Payback Framework is conceptually beneficial as it premises that by generating and sharing knowledge, research exerts influence (Belcher et al. 2020). The framework comprises the complete research process and links the research stages and the impact generated, thus describing how impact occurs (Penfield et al. 2014). It is a tool that collects data and provides a common structure for evaluating case studies and conducting cross-case analyses flexibly and intuitively (Donovan and Hanney 2011; Searles et al. 2016).

We have chosen the Payback Framework also as a basis for our framework for citizen science social innovation projects, not only because it is regarded as the best practice approach for impact assessment, and it can be adapted easily (Bornmann 2013; Donovan 2011; Penfield et al. 2014), but mainly because it combines the evaluation of the whole project process represented by the *logic model* and various impact categories presented in a *classification system* that captures five dimensions of benefits: knowledge, research benefits, political and administrative benefits, health sector benefits, and broader economic benefits (Donovan and Hanney 2011). It is widely accepted that the evaluation of research should consider the whole process and not only the outcomes (Schaefer et al. 2021), which is especially true for participatory evaluation in which the involvement of stakeholders varies in the different project phases (Springett 2017). In addition, the classification of the impact categories is sufficiently differentiated to cover all possible impacts but broadly enough to cover the wide range of social innovation projects. The two components of the Payback Framework are discussed below in more detail.

The logic model consists of seven stages (stages 0–6) and two interfaces. Figure 1 presents a graphical presentation of the model (Donovan and Hanney 2011). The seven stages assume an input-output perspective and delineate the underlying research project from its initial inception (stage 0) to its final outcome (stage 6) (Buxton and Hanney 1996; Donovan and Hanney 2011). The two interfaces are: 'Interface A: Project specification, selection, and commissioning' and 'Interface B: Dissemination, connecting the project with its environment, and embodying the interaction between researchers and potential users' (Greenhalgh et al. 2016). Feedback loops within the model ensure that the nonlinear processes of projects are considered (Greenhalgh, Raftery, Hanney and Glover 2016).

The classification system describes assessed benefits. The five dimensions from the original Payback Framework used for health research are two traditional academic-benefit dimensions: knowledge (e.g., academic publications) and research benefits (e.g., training new researchers). The other three dimensions of this study's model are related to broader societal benefits: political and administrative benefits (e.g., an information base for clinical policies), health sector benefits (e.g. cost savings), and broader economic benefits (e.g., commercial spin-outs) (Buxton and Hanney 1996; Donovan and Hanney 2011; Greenhalgh, Raftery, Hanney and Glover 2016). Benefits can arise at all stages of the logic model. However, some broad connections between stages and benefits exist; for example, benefits relating to broader societal benefits appear more often at later stages (Donovan and Hanney 2011).

It should be noted that when the Payback Framework is utilised in other areas, the health-related dimensions of the classification system, the second component of the model, must be modified (Klautzer et al. 2011). Adapting the Payback Framework to employment research, Klautzer et al. (2011) proposed to generalise the framework to the social sciences; the primary adaption was to substitute 'impacts on practice' for 'health sector benefits'. Despite adaptions for various sectors and projects, the application of the Payback Framework has been observed to retain most of its original structure and elements (Donovan and Hanney 2011).

Despite the framework's comprehensive and extensive approach and adaptability, limitations to its application and output exist. It has been criticised as labour-intensive and too project-focused (Greenhalgh et al. 2016). Furthermore, it is claimed that the complexity and interactive variables of research lead to a more sophisticated relation between inputs and outputs than it is presented in the framework (Pedersen 2020) and that the model does not capture factors like attitudes, skills, and relationships (Belcher et al. 2020). Moreover, when evaluation is performed by academics only, the process overlooks other relevant actors' impact as-

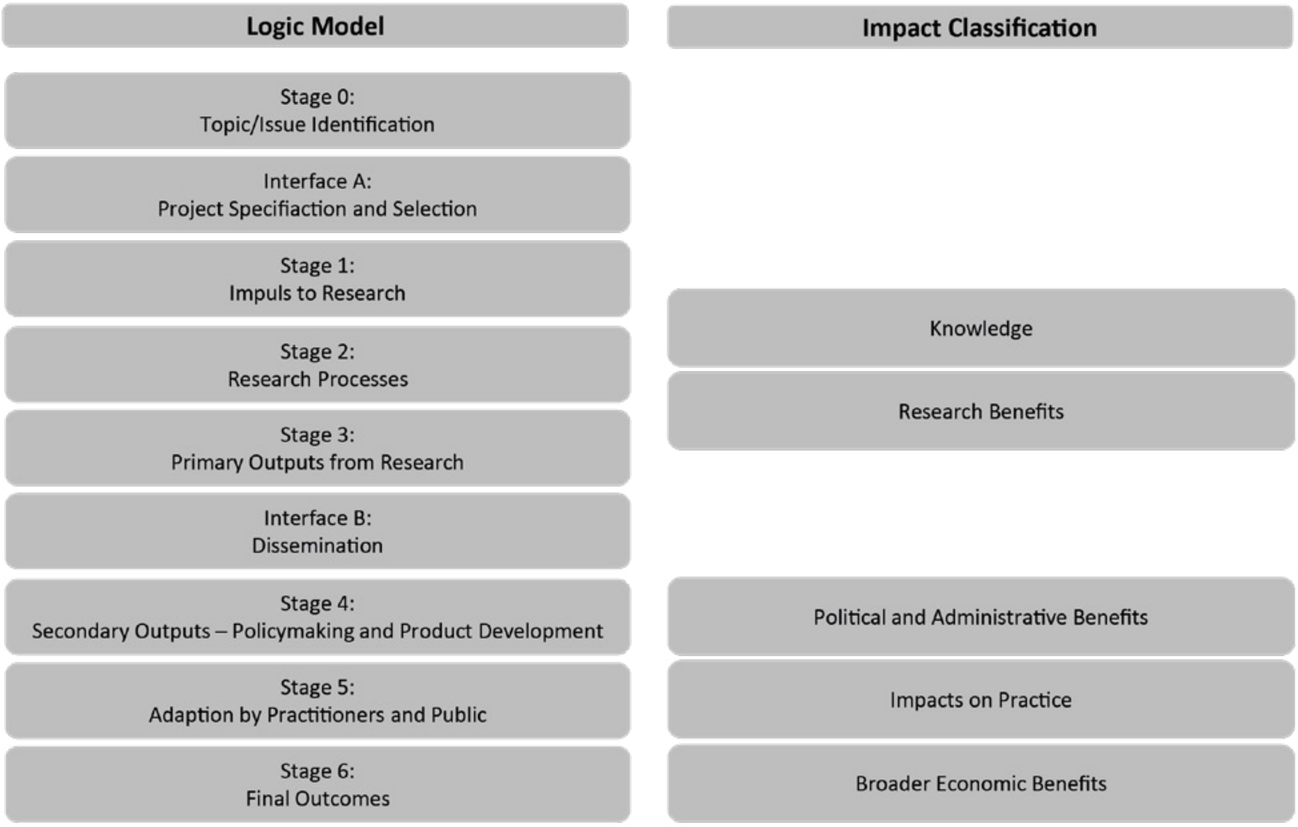

Figure 1: Logic Model and Impact Classification of the Payback Framework | Source: Authors' illustration based on Donovan and Hanney (2011)

sessments and experiences. This limitation has led some researchers to seek additional perspectives by conducting supplementary, semi-structured interviews with relevant actors, such as users or patients (e.g., Guthrie et al. 2015; Klautzer et al. 2011). Furthermore, while the Payback Framework's process, with its feedback loops, incorporates the non-linearity of projects, non-linearity is not accounted for in how knowledge is exchanged and generated between actors. Mainly for applications in social sciences and the humanities, the framework has been criticised for assessing the exchange of knowledge between HEIs and society too simply, instead of viewing it in a holistic network of actors and institutions as well as their complex interests and values (Belcher et al. 2020; Pedersen et al. 2020).

THEORY ADAPTATION: LOOKING AT THE PAYBACK FRAMEWORK THROUGH AN S-D LOGIC LENS

Although the Payback Framework is a commonly accepted framework for research projects, its academic focus and linear understanding of knowledge transfer limit its appliance to citizen science projects for social innovation. This study's use of the theory-adaptation approach aimed to overcome these limitations by introducing another theoretical lens to an existing theory, the holistic lens of the Service-Dominant logic (Jaakkola 2020). In this case, the existing theory, referred to as domain theory, was the Payback Framework, while S-D logic served as the 'new' lens, called method theory. By integrating the co-creative, interactive nature of S-D logic, the observed gaps of the Payback Framework could be bridged, and its application domain extended to citizen science projects for social innovation.

In this study, the first step of the theory-adaptation process was to understand the lens of S-D logic and its applicability to the field of citizen science. S-D logic emerged in 2004 when Vargo and Lusch challenged the traditional view of creating value. S-D logic presents a continuing narrative of value co-creation that is applied in various academic disciplines, for example, in innovation research (Vargo and Lusch 2017). In the traditional marketing view, the firm creates and delivers value in the form of goods and services. S-D logic describes all actors, including the firm and the customers, as equal actors creating value through interaction and collaboration (Jaakkola and Alexander 2014; Vargo and Lusch 2004). Since this understanding of all resource integrators as equal actors overcomes the distinction of producer and consumer, the value creation process is defined as a co-creation process (Vargo and Lusch 2004).

Transferring this perspective to academia and social innovation projects makes it applicable to citizen science, a field characterised both by the increasing participation of previously non-involved and non-engaged actors in academic projects and by the degree of power allocated to those actors. Following S-D logic, academia can be equated to firms that create value within and beyond the scientific sector in a co-creation process with citizens.

Resources are a central concept in S-D logic. Following the resource-based view of value creation, resources are defined as anything that enables an actor to create value. Resources are integrated into the process of co-creation (Vargo and Lusch 2008). However, in S-D logic, resources are not only physical but are also intangible, including, for example, knowledge and skills (Vargo and Lusch 2008). In S-D logic, actors play underlying roles as resource integrators; that is, actors, bring together their unique resources to create value. Resource integration is shaped by actors' knowledge, skills, intentions, and motivation (Edvardsson et al. 2014). A similar resource-integration practice can be seen in citizen science projects, benefiting the projects significantly. Academic actors bring in academic resources (e.g., material equipment, but also theoretical knowledge and methods), while non-academic actors contribute non-academic resources (e.g., practical knowledge, needs, and experiences).

Recently, there has been a growing understanding that no co-creation process occurs in isolation; the process always occurs within nested and interlocking service ecosystems (Vargo and Lusch 2016). Vargo and Lusch (2016, p. 161) define a service ecosystem as a 'relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange'. Through the lens of S-D logic, institutions, sectors, or disciplines present different ecosystems that can overlap and build a complex and interrelated resource-integration arrangement around a purpose, namely the innovation process (Vargo and Lusch 2016). In citizen science projects for social innovation, these ecosystems may encompass HEIs, on the one hand, and segments of cooperative society, on the other hand. Considering the innovation process from an S-D logic perspective implies that a project's ecosystems offer the relevant structures for actors as resource integrators and value co-creators within the innovation process (Aal et al. 2016).

In summary, S-D logic provides a promising holistic and dynamic lens to understand and describe the participatory nature of citizen science since it overcomes the distinction between producer and user by describing all participants as resource integrators who co-create value. The focus on the actors as resource integrators captures the collaborative way in citizen science social innovation projects, in which academics and citizens collaborate to co-create a social innovation to overcome social challenges.

In the second step of the theory-adaptation process within this study, S-D logic was applied to the Payback Framework to address the two known limitations of its applicability to citizen science projects, identified previously as the framework's purely academic view on impact evaluation and its linear knowledge generation. The understanding of all participants of the collaboration process as equal actors who are integrating their resources, the S-D logic allows overcoming the linear knowledge transfer conceptualisation of the Payback Framework to reflect the current co-creation approach of knowledge generation in academia (Greenhalgh et al. 2016). This holistic approach can not only be applied to the knowledge generation but also to the evaluation process, aiming for a participatory evaluation understanding (Springett 2017).

The two pre-existing components of the Payback Framework (the logic model and the benefit classification system) do not adequately represent the participatory approach of citizen science and the co-creative nature of S-D logic. Therefore, a third component of the Payback Framework was introduced: the level of citizen participation. This new component was added to evaluate the degree of citizen participation in the logic model's activities to indicate the citizens' participation in the evaluation process.

The citizen participation component in the new framework has direct links to each stage of the logic model and Interface A (Project specification and selection) and Interface B (Dissemination). At each stage of the logic model (including Interface A and Interface B), the extent to which citizen participation is enabled within the project is specified, allowing for an individual, stage-specific description of citizen participation in each project. The evaluation of citizen participation is made by judging the intensity of current participation compared to the maximum participation possible (equalisation of the actors – how it is conceptualised in the S-D logic). There are four potential levels of citizen participation in a project: *no participation*, *contribution*, *collaboration*, and *co-creation*. These levels were defined according to the four stages of citizen participation in the research process of citizen science projects and were differentiated by the amount of power and control given to the participating non-academic actors (Bonn et al. 2016; Bonney et al. 2009). The definitions account for the fact that non-academic actors can be differently engaged in the stages of the Payback Framework's logic model. Once all stages of a project have been evaluated, a general evaluation of citizen participation can be achieved by considering the overall degree of citizen participation in the project.

The four levels of citizen participation have different implications. Generally, with growing allocated power and participation, non-academic actors gain more awareness, knowledge, and understanding of the project (Bonney et al. 2009). Thus, (0) *no participation* implies that the old Payback Framework structure with its academic perspective and unidirectional knowledge generation is retained. (1) *Contribution* means that a limited degree of participation is present, i.e., non-scientific actors gathering data and information. (2) *Collaboration* of non-academic actors implies that they participate to a moderate degree, perhaps by analysing data or disseminating societal outputs. Finally, (3) *co-creation* means that non-academic partners are actively involved and participate fully in the project as equal partners. Depending on the level of participation, the citizens should be included in the evaluation of the project stage in various manners, from specifying the purpose of the evaluation, formulating the evaluation question, collecting the data, interpreting the data, and acting on the results (Springett 2017).

The described CSP Framework is presented in Figure 2. The Figure highlights the interplay of the framework's three components, with the evaluation of external participation on the left as a starting point, the logic model at the heart of the framework, and the benefit dimensions on the right, positioned close to where they are most likely to arise.

The proposed CSP Framework benefits from its comprehensive yet inclusive structure. It utilises the process steps of the logic model of the Payback Framework, as well as the application of its impact categories and considers non-academic actors and their contributions at all possible stages of the process. The new framework enables a citizen science project's holistic and inclusive evaluation and categorisation based on actual levels of citizen participation.

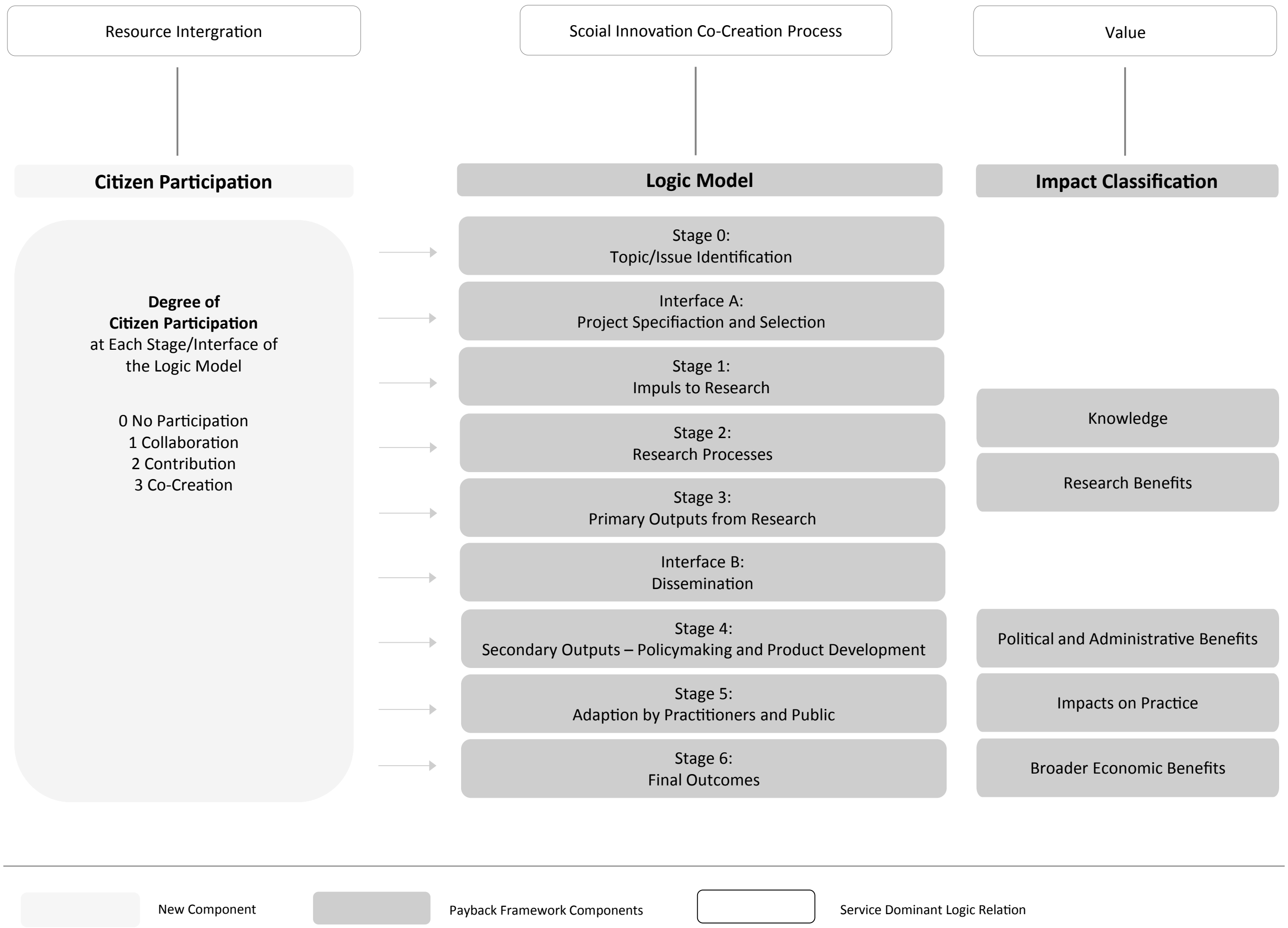

Figure 2: Citizen Science Payback Framework (CSP Framework) | Source: Authors' illustration

CONCLUSION

THEORETICAL CONTRIBUTIONS

The study contributes to the existent academic literature in the fields of evaluation and citizen science. Notably, it demonstrated how the frequently exerted Payback Framework could be extended to apply to citizen science projects for social innovation. The expansion was accomplished using the theory-adaptation approach. This approach creates academic value by connecting different academic fields of knowledge (Jaakkola 2020). The Payback Framework originates in health science, while S-D logic is part of marketing theory. While both the Payback Framework and S-D logic have been applied in various academic fields, to our knowledge, this study is the first to apply them jointly in the area of citizen science. The study demonstrated how the co-creative nature of S-D logic enriches the previously purely academic focus of the Payback Framework and allows for consideration of the dynamic knowledge generation between different actors.

The resulting conceptual CSP Framework, with its third component, introduces a participatory evaluation and impact assessment model for citizen science projects for social innovations and contributes to the theoretically and conceptually underdeveloped field of participatory impact evaluation (Smit and Hessels 2021; Springett 2017).

PRACTICAL IMPLICATIONS

Adaptations that have resulted in the proposed CSP Framework offer two potential applications for practitioners. First, the CSP Framework can be used to compare projects and proposals. There is still no one-size-fits-all model (Greenhalgh, Raftery, Hanney and Glover 2016), but with a similar structure and benefit dimensions as the Payback Framework, the CSP Framework makes possible comparisons of citizen science projects for social innovation that vary in implementation and scope. Comparisons through the CSP Framework have the potential to justify public funding and support for academic projects (Bornmann 2012; Greenhalgh, Raftery, Hanney and Glover 2016), thus creating a further incentive for academic actors to create more societally relevant projects and to include non-academic actors in projects. Second, the framework can evaluate citizen science projects for social innovation using a defined structure. Looking to the future, a more co-creative evaluation process may influence projects in the long term. As project evaluations influence and determine the projects that are pursued in the present and future by creating incentives and guidelines, a participatory approach to the evaluation process may make the entire project focus itself more participatory. As proposed in the S-D logic and the innovation and participatory evaluation, this contribution assumes that higher participation of citizens leads to better project processes and outcomes (Senabre Hidalgo et al. 2021; Vargo and Lusch 2017), but this might not be applicable in all citizen science projects.

FUTURE RESEARCH AND LIMITATIONS

Although the S-D logic offers a holistic and inclusive perspective to overcome the limitations of the Payback Framework and captures the participatory nature of citizen science, by utilising the understanding of a co-creative resource integration process of various actors leading to value generation, the extension of the framework by the new component could be considered as superficial. How the citizens' participation can be evaluated and how exactly they could be included in the evaluation process remains unclear. The S-D logic as a macro theory must be enhanced by a bridging micro theoretical approach for a more precise conceptualisation. Nevertheless, not only a further and more detailed conceptualisation of the model is needed, the model should be empirically tested and thus operationalised in a further step. The merely theoretical conceptualisation of the model could have led to critical issues being overlooked that may surface in the operationalisation phase and the practical application. While the study's proposed CSP Framework allows citizens to be part of the project evaluation process, it does not yet include an assessment of the success of co-creative practices and evaluation factors like trust and relationships (Belcher et al. 2020). The new component captures the extent of the citizen participation, but the contribution of the interaction, rather than its attribution, must be considered further (Spaapen and van Drooge 2011). Another task for future research may be to determine if the CSP Framework can be applied to all citizen science projects and not simply to those for social innovation. Innovation projects are characterised by the collaboration of various actors from different sectors, but this does not apply to other citizen science projects. Here it should be determined whether the model is also applicable to other citizen science projects or should be modified accordingly.

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KEYWORDS
Citizen Science; Payback Framework; Social Innovation; Evaluation; Impact-Assessment

PRAXIS REPORT

QUALITY ASSURANCE INDICATORS FOR ENVIRONMENTAL CITIZEN SCIENCE

DEVELOPMENT OF INDICATORS FOR VOLUNTEER-BASED BIODIVERSITY MONITORING

ANETT RICHTER

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ABSTRACT

Volunteer-based biodiversity monitoring schemes are currently developed and tested for feasibility in and for agricultural landscapes in Germany. For the assessment of the effectiveness and efficiency of volunteer-based biodiversity monitoring schemes, indicators are required but so far, such indicators have neither been developed nor tested. Here, sets of indicators are developed and presented based on evidence from scientific literature and from the volunteers' perspectives. As a starting point of the development of indicators, challenges for volunteers need to be identified that may hinder them from taking part in the schemes and from achieving project goals. On the basis of formulated actions to overcome these challenges, three sets of indicators are derived, covering the areas of i) capacity building for volunteer-based engagement, (ii) appreciation and valuing of volunteer commitment, and (iii) education and learning in volunteer-based approaches. Indicators are developed to potentially serve internal and external communication and act as project quality assurance measures. At the same time, the presented indicators may potentially also be applied by decision-makers in policy as well as by funding agencies. In a next step, indicators are co-developed using participatory evaluation approaches to combine conventionally developed indicators with indicators developed with members of the community of practitioners. Implementing indicators in practice as well as regular reflections and revisions will ensure an adaptive quality assurance system for volunteer-based biodiversity monitoring and beyond.

1. INTRODUCTION

1.1 THE SIGNIFICANCE OF VOLUNTEER-BASED BIODIVERSITY MONITORING

The majority of international and national biodiversity monitoring schemes have been established by non-governmental and volunteer-based initiatives and hosted and supported by national and regional NGOs and informed society. Some schemes are supported by academia via infrastructure and personal. Over 80% of biodiversity data on biological diversity (presence, absence, numbers of species of plants and animals) are gathered by the very heterogenous group of dedicated volunteers (Chandler et al. 2017; Schmeller et al. 2009; Henle et al. 2013). Sets of data collected by volunteers are geographically, as well as taxonomically, fragmented (Pocock et al. 2015a). Some schemes follow strict protocols and generate semi-structured data, others are based on so-called opportunistic data – referring to data that originates from the volunteer's decision about time and location of the observation and the selection of the observed and recorded species (Kelling et al. 2019, Tulloch et al. 2013). Despite the challenges associated with the heterogeneity of biodiversity information (e.g. data and scales) and technical and stakeholder network designs in biodiversity monitoring (Kühl et al. 2019), monitoring of plant and animal species will always rely on the engagement of volunteers with restricted access to areas and regions, time and resources required for monitoring.

Thus, it is one of the greatest challenges to design and perform biodiversity monitoring in such way that the quality and quantity of the biodiversity data and information required by the formalised academic knowledge system are guaranteed. At the same time, the volunteers' personal motivation for participation and engagement in monitoring activity must be acknowledged and considered (Richter et al. 2020, Pocock et al. 2018).

In Germany, approximately 50% of the total area is used for agricultural land use. Therefore, agricultural landscapes play an important role in the conservation of biological diversity. Despite current knowledge that much of the decline of biodiversity is closely linked with the composition and configuration of agricultural landscapes and how these landscapes are managed (Buhk et al. 2017, Burns et al. 2016), most conclusions about the status of biodiversity in agricultural landscapes in Germany are drawn based on a limited set of data and information. For scientifically informed policy decisions (e.g. how to best conserve biological diversity in agricultural landscapes), monitoring schemes of biodiversity are needed to provide reliable information about the status quo of biological diversity and to make informed calls for specific actions for the conservation and rehabilitation of biological diversity. In the framework of developing such a national monitoring scheme of biological diversity for agricultural landscapes (MonViA) in Germany, standardized recording methods and indicators are developed and tested for the performance of trend analyses of the status and development of biological diversity in agricultural landscapes. As monitoring schemes, in general, largely on volunteers, the significance of volunteer-based biodiversity monitoring in the MonViA context is enormous. Current goals of the developed volunteer-based monitoring schemes are a) to support data-driven trend monitoring schemes by providing complementary sets of data and information on aspects of biodiversity on farms and in rural areas and b) to facilitate learning and participation processes to accompany the transition towards sustainable agriculture.

1.2 AIMS AND OBJECTIVES OF THE INVESTIGATION

Biodiversity monitoring depends on volunteers to willingly initiate and perform tasks involved in monitoring and to openly take part in learning processes in today's and future biodiversity schemes. Therefore, the perspectives of volunteers must be integrated when developing these schemes. This also accounts for the associated development of indicators in volunteer-based biodiversity monitoring, with the purpose of quality assurance in citizen science.

Here, I understand indicators as measures that qualitatively and quantitatively manner progress in projects or programs as well as associated outcomes. Indicators for volunteer-based monitoring of biological diversity in agricultural landscapes will have communication, moderating and regulating functions. First and foremost, they are developed as tools to assess how effective the schemes are coordinated and how successful processes and outcomes are communicated. In the context of assessing the communication, indicators contribute to a factual discussion about the concrete outcomes and outputs of the monitoring scheme. In the sense of a regulating function, indicators allow to objectively assess the achieved volunteer-based monitoring results as well as tools for recording any changes within the monitoring.

The aim of this investigation is to develop sets of indicators for volunteer-based biodiversity monitoring for use by the community of practitioners, serving as infrastructure for future biodiversity monitoring schemes in agricultural landscapes. In this context, the following questions are addressed:

- What are the factors the prevents volunteers from or motivate them to engage in biodiversity monitoring?
- What are the challenges when it comes to achieving goals in biodiversity monitoring?
- What kind of actions are needed to make volunteer engagement easier?
- How can these actions be measured to report and to communicate the success of volunteer-based biodiversity monitoring?

1.3 BACKGROUND: THE MISSING PERSPECTIVE AND LINKS

For Citizen Science - as an approach of voluntary engagement in scientific projects in compliance with scientific standards (Bonn et al. 2017) - quality criteria ensuring and promoting the quality of citizen science projects are in place (Heigl et al. 2018). Criteria are used particularly to determine if a citizen science project is suitable for national online networks (e.g. Österreich forscht, Bürger schaffen Wissen). Criteria are developed from the perspective of the network initiators who apply unified quality criteria to ensure high standards of the network. Criteria such as the ten principles of citizen science are developed from the perspective of the citizen science community. Here, they serve as guiding principles for the design and implementation of citizen science projects (Robinson et al. 2018). For biodiversity networks supported by citizen science, Vohland et al (2016) developed success criteria for networks and identified success as an intersection of program quality, quantity, and accessibility. These criteria were developed from the perspective of project and program initiators and integrate quantitative and qualitative measures. In contrast, the work by Kiesslinger et al. (2018) on the evaluation of citizen science proposes the evaluation of citizen science programs on three main dimensions of participatory scientific processes. These dimensions include i) scientific impact of the project, (ii) learning and achievement of qualification of individual participants as well as (iii) recording the impact on society. Th evaluation framework developed by Kiesslinger et al. (2018) integrates science and social science perspectives and is developed from the perspective of citizen science funders and supporters as a tool for informed decisions.

The basis of citizen science builds upon cooperation between volunteers and members from academia. In some cases, the activity is performed without any involvement of science. Any citizen science project depends on the engagement of people and it would be impossible without the interest of people in project topics and their commitment. Volunteers spend their personal time on the project, they devote energy to the tasks associated with it, and share the knowledge derived from the activity. As a consequence, it seems indispensable to re-think the development of indicators to assess the project success from the volunteer's perspective.

Central to this is an understanding about the role of group tasks, such as being part of a group of like-minded people that voluntarily observe and record plant and animal species. Research shows that group tasks rely in large part on individual willingness (Eddy-U 2015). Personal willingness affects the motivation related to the group tasks, whereas the motivation is affected by the task attractiveness as well as by the task feasibility. Both, social factors (e.g. those associated with individual needs and conditions) and task-related factors, impact personal willingness and consecutively the (non) motivation of group tasks (Figure 1).

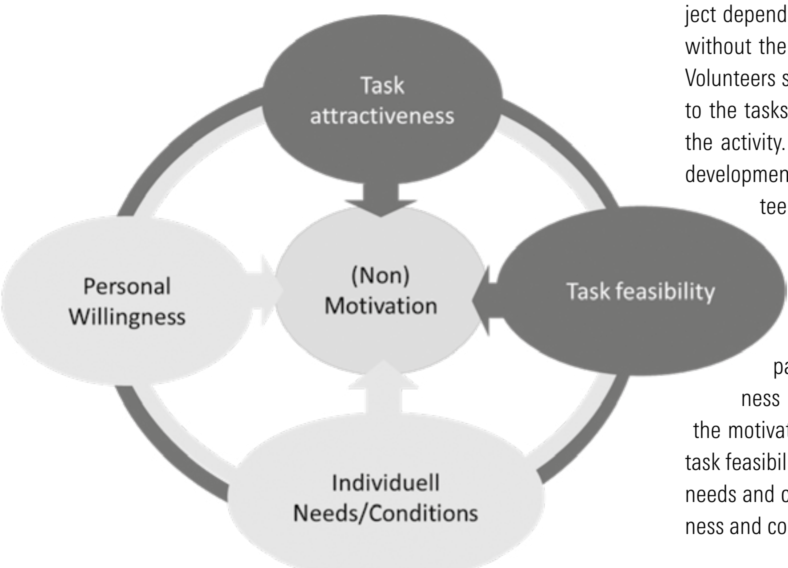

Figure 1: Schematic illustration of the interactions of social factors (yellow) and task-related factors (blue) impacting personal willingness and (non) motivation for group tasks. The interrelatedness of the factors is indicated by the two-colored circles. Figure modified and adapted from Eddy-U (2015).

In the construct of interactions of social factors and task-related factors impacting personal willingness and (non) motivation for group tasks, the factor of volunteer recruitment needs consideration. In the practice of citizen science, citizen science managers and coordinators apply recruitment-, communication- and engagement strategies to ensure that volunteers are satisfied with their volunteer experience and maintain motivated to take part in citizen science (Clary et al., 1998; Ng et al., 2018). This becomes particularly important when international schemes are desired for long-term monitoring to assess global biodiversity (Richter et al. 2021).

2.METHODS: THE STEPS INVOLVED IN THE DEVELOPMENT OF INDICATORS

Indicators are developed for application in volunteer-based monitoring approaches; based on barriers and challenges participants encounter when engaging in ecological and environmental citizens science. The term ecological and environmental citizen science is used as an overarching theme to cover the diversity of approaches in ecological and environmental citizen science projects (Pocock et al. 2017), including systematic and non-systematic monitoring (Pocock et al. 2017). It is acknowledged that much knowledge exists about the opportunities and potentials of ecological and environmental citizens science (Turrini et al. 2018, Brown and Williams 2019, Pocock et al. 2017). However, this work presented here deliberately focuses on the barriers and challenges faced by participants in ecological and environmental citizen science to capture their real-life challenges and experiences.

In the first step, sets of reasons hindering or enabling citizen and stakeholder engagement in agricultural research were identified at the first Thünen-Citizen Science Conference in 2020 (Richter et al. 2020). The lunch to lunch conference entitled "Citizen Science—New Participation Format for Research in the Agricultural, Forestry, Fisheries and Rural Areas" took place in March 2020 in Braunschweig. More than 30 participants from the Thünen Institutes and partner organizations with an interest in learning more about citizen science to add to their experiences in participatory research in rural areas took part in this conference.

Four rounds of roundtable discussions were set up to discuss challenges in contemporary participatory research and citizen science in the context of agricultural sciences. At each table, key questions guided the discussions that were moderated and recorded. The main points of the discussion were transcribed verbatim using posted notes. A person who was not participating in the round table recorded the main statements from the discussion. All information gathered was analyzed thematically. Participants were asked to report on their experiences and research findings related to participants' viewpoints for voluntary participation in research.

In the next step, a scoping literature review was performed in the order of the following steps: identification of relevant studies and selection of literature and collection of information, and reporting of the results. The process was adopted from the five-step approach presented by Arksey and O'Malley (2005). The search strategy included a literature search using combined keywords derived from the roundtable discussion (e.g., citizen science AND challenges, personal barriers AND citizen science). Also, I applied keyword searches on terms e.g., species skills taxonomy, identification skills volunteers, and understanding concept biodiversity. The search was performed in German and in English using online literature platforms Google Scholar and "Web of Science". The search applied a forward and backward snowballing procedure. The well-established method is suitable for identifying important articles relevant to a topic of interest and implies both, finding citations to a paper and findings citations in a paper (Jalali & Wohlin, 2012). The output of this step is a catalog of factors hindering participation and associated literature supporting these factors from studies about volunteer commitment.

In the third step, actions were formulated to overcome hindering factors for volunteer commitment. For this, all factors were coded using six categories previously identified in step 1. The development of categories was in line with the approaches and levels of participation as outlined in the Green Book for the German Citizen Science Strategy 2020 (Bonn et al. 2016). From here, for each factor actions were identified or, in case the action was already listed, added as a factor to that action. This way, a list of actions and linked factors was developed.

In a final step, qualitative and quantitative indicators were derived for the prioritized actions and presented as sets of indicators. The development of indicators followed the guidelines for a consolidated Citizen Science Impact Assessment framework (When et al. 2021). The six guiding principles were adapted towards a participant perspective and identified barriers to participating in citizen science-based monitoring of biological diversity. The indicator development acknowledged the variety of purposes of indicators and the importance of qualitative as well as quantitative measures. Also, the need to apply indicators across citizen science projects and the purpose of further developing and testing the indicators using mixed approaches were acknowledged. The output of this step is a set of indicators related to pre-identified actions required to overcome the barriers to participation.

3. FINDINGS

At the roundtable discussion, several factors were identified that hinder participation in citizen- and stakeholder engagement in agricultural research. Factors considered as barriers are: "lack of knowledge", "lack of digital know-how", "insufficient digital infrastructure to use applications for recording biological diversity", "lacking spare time" as well as "missing access, e.g., to initiatives originated by academia". Further, the factor "receiving appreciation for the engagement and participation" is still not adequately honored in society and is considered a barrier to participation.

The findings from the roundtable discussion identified social and task-related factors affecting the participation. The literature search identified further social-related factors and complemented the list of factors derived from the roundtable discussion (Table 1). When grouping the factors, it became clear that factors cover aspects of people's challenges (eight factors) and also challenges associated with biological monitoring (five factors). Further, five factors were identified that can be grouped into the category of societal challenges. The analysis made clear that a connection exists between barriers and challenges and the achievement of the aims and objectives of a project or scheme, as well as related outputs (Table 1).

Categories	Factors challenging participation	Literature
People (FP)	Age, ethnic imbalance	Theobald et al. 2015, Burgess et al. 2017, National Academies of Sciences, Engineering, and Medicine. 2018, Statistica 2018
	Insufficient knowledge about the possibilities to participate	Moczek et al., 2018, Ockenden et al., 2007, Unell et al., 2012
	No time capacities	O'Brien et al., 2010, Freiwilliges Engagement in Deutschland (2001)
	No interest or motivation	Walz et al., 2012
	No interest in volunteering	Freiwilliges Engagement in Deutschland (2001)
	Taxonomic species knowledge	Frobel and Schlumprecht 2014
	Voluntariness	Penner, 2002
	Insecurities in dealing with other people	Walz et al., 2013, Moczek et al., 2018
Biological Diversity (FBD)	Plants and animal species are difficult to identify and ways of learning how to identify them are needed	Mitlacher and Schulte (2005)
	Habitat structures are difficult to identify and to assess	Mitlacher and Schulte 2005
	Unfamiliar with the concept of biodiversity	Hunter and Brehm 2003, Lindemann-Matthies and Bose 2008, Fiebelkorn and Menzel 2013
	Recording exclusively via habitat structures/technologies and no direct contact/lack of emotional connection with the actual object	Schemel 2008
	Erosion of taxonomists	Frobel and Schlumprecht 2016
Societal factors (FSF)	Lack of recognition and feedback within the community	Walz et al.; 2013
	Lack of recognition and feedback within the community	Bonney et al., 2009
	Lack of community and communication within the community	Moczek et al., 2018, Ryan et al.; 2001
	Prioritizing other voluntary activities (sports, culture, digital)	Frobel and Schlumprecht 2016
	Discrimination and degradation of social status	Behlau 2002, Trommer 2015
Generation of knowledge (FKG)	Incorrect or no knowledge about biological diversity	Schulemann-Maier et al., 2018
	No appreciation of knowledge as common property to be used by many	Ostrom 2011
Learning & Understanding (FLU)	Different learning types and motivations	Schulte et al., 2019
	Insufficient transfer of knowledge about biological diversity	Moczek et al., 2018
	Specific learning vs. process-oriented learning	Moczek et al., 2018
Active participation (FTT)	Concern about no "real" participation (pseudo-participation)	Kubicek et al., 2009
	Personal restrictions	Freiwilliges Engagement in Deutschland (2001)

Table 1: Overview of categories and associated factors (with codes) related to challenges in participation found in literature.

Goals, as identified by Turrini et al. (2018) as the threefold potentials in environmental citizen science, include the generation of new knowledge, learning, and understanding as well as active participation (Figure 2). Seven additional factors were identified that affect the achievement of goals and outputs in environmental citizen science (Table 1). In total, a catalogue of 25 factors was identified that hinder participation in citizen science-based monitoring and environmental citizens science from a volunteer perspective.

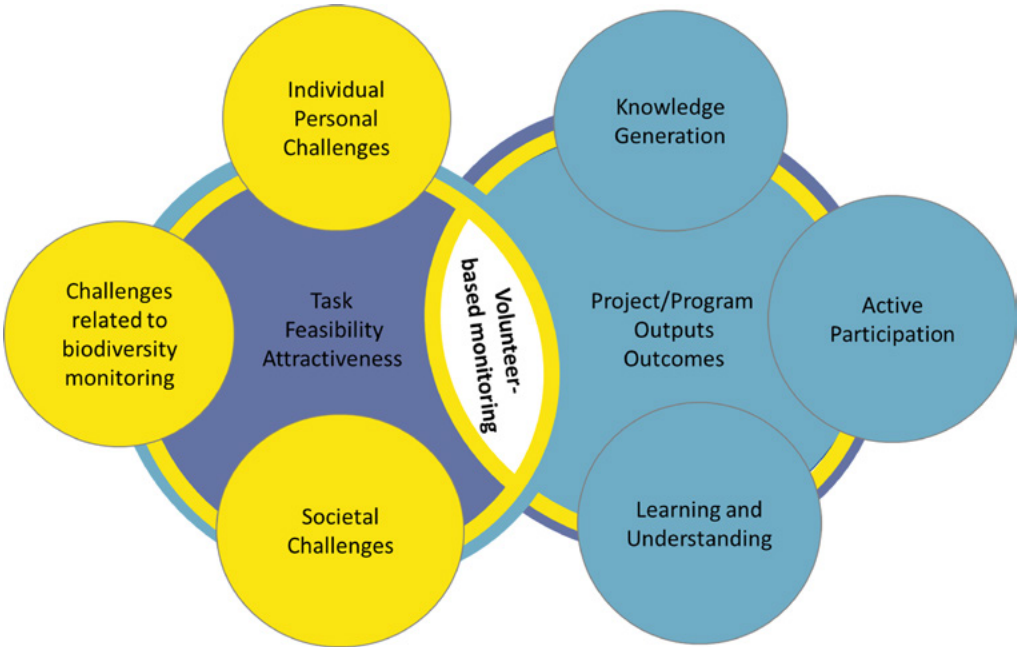

Figure 2: List of social factors (yellow) and task-related factors (dark blue) that impose a challenge to participation as well as to achieving outcomes and outputs in environmental citizen science and in volunteer-based biodiversity monitoring (light blue). The interrelatedness of the factors is indicated by the coloured circles.

3.1 INDIVIDUAL FACTORS THAT CONSTITUTE CHALLENGES AND BARRIERS FOR VOLUNTEERS TO PARTICIPATE IN ECOLOGICAL AND ENVIRONMENTAL CITIZEN SCIENCE

First and foremost, the lack of interest or motivation refrain people from engaging in ecological and environmental citizen science. In fact, Walz et al. (2013) show that lack of interest and no motivation are the greatest challenges when it comes to recruiting people for voluntary nature conservation. In Germany, nearly 40 percent of residents aged 14 and older are engaged in some kind of voluntary work. However, a large proportion of the population is not involved in any voluntary work (Freiwilliges Engagement in Deutschland 2001). 3.5% of all active volunteers engage in nature conservation activities (Moczek 2019).

Key factors affecting voluntarism include personal circumstances and individual attributes such as age, social, educational, and economic status, along with the kind of associated organization and communication within organizations (Penner 2002). For those interested in volunteering work, factors such as having no time capacities to engage in nature conservation activities (O'Brien et al. 2010), and recent shifts in the amount of time available for volunteer engagement, are identified as important barriers for engagement (Freiwilliges Engagement in Deutschland 2001). Today, volunteers in Germany generally spend less time on voluntary activities than they did fifteen years ago. Between 1999 and 2014, the number of volunteers who devote six hours or more per week to voluntary activities decreased. In contrast, the proportion of those spending up to two hours a week increased by 58 percent (Freiwilliges Engagement in Deutschland 2019).

In some cases, people do not participate in voluntary activities due to a lack of knowledge about existing opportunities to do so. Recent research on how people learn about such opportunities in environmental citizen science shows that it is most effective to recruit people in conservation projects via personal communication (Ockenden et al. 2007, Unell et al. 2012). For example, more than half of the participants in the BUND Wildcats Project found out about the project through personal contacts between project coordinators, friends, and/or via family members (Moczek et al. 2018).

Some people distance themselves from community activities because they do not feel confident dealing with other people (Walz et al. 2013). Some people consider mutual exchange of knowledge, skills, and experience between citizens and scientists the greatest added value of citizen science projects (Moczek et al. 2018), others want to gain competencies in leading rounds of discussions and resolving conflicts and, thus, overcome their insecurity to talk and discuss with other community (Walz et al. 2013).

Another individual factor hampering engagement is the imbalance within the group of participants in many environmental citizen science programs. Demographic analysis in the US shows that predominantly male, white (88.6% in biodiversity projects), well-educated people participate in citizen science. In addition, they often tend to have previously participated in other projects (Theobald et al. 2015, Burgess et al. 2017, National Academies of Sciences, Engineering, and Medicine. 2018).

For Germany, less information about demographic variables in volunteers is available. However, census data show that one third of all volunteers in Germany are retirees, with around 23% of German volunteers being older than 70 years (Statistica Report 2018). Analysis of citizen science projects in Germany in the Humanities and Social Science by Göbel et al. (2020) showed that people engaged in these projects are predominantly males over 50 years of age, with an academic background. Moczek et al. (2021) presented similar findings for citizen science in the

Natural Sciences: again, the community is male-dominated and highly educated. In conclusion, participants in many citizen science projects do currently not represent the diversity of citizens. This imbalance may hold back participation of those sharing other characteristics.

3.2 MONITORING OF BIOLOGICAL DIVERSITY-SPECIFIC FACTORS CHALLENGING VOLUNTEERS TO PARTICIPATE IN VOLUNTEER-BASED MONITORING APPROACHES

Volunteer engagement in monitoring schemes is associated with several factors. One of the greatest challenges is to get in contact with monitoring schemes that focus on biodiversity. Numerous empirical studies showed that people are not familiar with the concept of biological diversity (Hunter & Brehm 2003, Lindemann-Matthies & Bose 2008, Fiebelkorn & Menzel 2013). Another barrier, inherent to monitoring of biological diversity, is the fact that plant and animal species, which build the foundation of biological diversity, are highly diverse and difficult to identify. Mitlacher & Schule (2005) showed that NGO members saw great need for educational units to increase methodological competencies for species identification and species observation. This is accompanied by a high demand for courses for qualification in species and biotope protection, nature conservation law, and participation procedures (Mitlacher & Schulte 2005). Thus, limited knowledge and confidence may also hamper engagement in monitoring.

Nowadays, many biological diversity observations and recordings are carried out with the help of digital technology or are performed completely disconnected from nature (e.g. photo ID tasks of camera trap pictures). Schemel (2004) found that missing emotional contact with the original object of interest may lead to negative motivation for participation in nature conservation. Therefore, in order to maintain a high motivation for voluntary commitment in nature conservation, a strong emotional bond with nature is necessary (Schemel 2004).

Finally, our findings show that the erosion of taxonomists over the past 20 years (Frobel & Schlumprecht 2016) also act as a challenge for participation in monitoring schemes. Awareness these schemes is often raised by people who are skilled, highly knowledgeable and enthusiastic about biological diversity. Without experts and mentors of taxonomy that slowly draw particularly young people's attention to species identification, and to methods in monitoring of biological diversity, and who share their expertise and knowledge, access to these schemes is also prevented.

3.3 ADDITIONAL FACTORS CHALLENGING VOLUNTEERS TO PARTICIPATE IN ENVIRONMENTAL CITIZEN SCIENCE

I found several other factors to affect the conditions for volunteer engagement in environmental citizen science. These factors include low societal appreciation for volunteer engagement, the absence of a community of like-minded people as well as the fear of discrimination and social degradation due to volunteering in environmental citizen science.

In their German-based studies, Behlau (2002) and Trommer (2015) describe that specifically young people engaged in environment and nature conservation are referred to as "Ökos (a negative narration derived from the word ecologist, freely translated as "tree huggers"). Young people with an interest in nature conservation are often perceived as outsiders and considered "uncool". This form of discrimination and the fear of being labeled are presumably putting young people off volunteering in environmental citizen science.

Also, lack of societal recognition for engagement, in the sense of a culture and recognition of volunteering at various levels, together with missing feedback from within the community, is expected to affect people's interest in environmental citizen science. A German-based survey showed that recruiting young people for voluntary nature conservation was mainly challenged by the self-assessed lack of recognition by society (Walz et al. 2013). Nearly half of the respondents feel that their work is not sufficiently appreciated by the public and media. None of the interviewed environmental associations felt sufficiently valued by national, regional and local politics (Walz et al. 2013).

Interestingly, Bonney et al. (2009) showed that participant numbers in eBird tripled after a re-design of the platform. After the make-over, participants were able to access their data and to discuss them with others. In addition to an increase in appreciation from within the community, Moczek et al. (2018) and Ryan et al. (2001) showed that personal contacts among members also promote volunteer engagement. Not only are these contacts important in order to learn about the project, but social factors such as assembling, meeting and sharing information as well as experiences are also decisive for long-term volunteer engagement.

I should also consider the external factor of a shift of interests. Frobel and Schlumprecht (2016) recognized that the behavior of young people and, in particular, the way how they prefer to spend their leisure time have changed. Nowadays, young people spend much of their spare time using digital technologies and social media. The authors consider these trends "a distraction" from spending time outdoors and missed opportunities, e.g. to observe and record species.

In total, I found a comprehensive set of factors challenging the engagement of people in environmental citizen science and volunteer-based monitoring approaches. Factors that cover individual reasons are predominantly and complemented by factors specific to monitoring activities as well as by external factors adding pressure on individual decisions, interests, and positions towards volunteered engagement.

3.4 ENVIRONMENTAL CITIZEN SCIENCE-RELATED FACTORS CHALLENGING THE ACHIEVEMENT OF PROJECT GOALS

Individual factors affecting the engagement of the volunteers are closely related to factors challenging the achievement of project goals and objectives in environmental citizen science. Here, I present and assess challenges for the three main goals in environmental citizen science: (1) the generation of knowledge, (2) learning and understanding, and (3) participation.

Incomplete and/or incorrect data on biological data and a lack of interest to acknowledge local and regional knowledge domains as common goods are considered great barriers for the generation of new knowledge in biodiversity. Schulemann-Maier et al. (2018) found that many active nature enthusiasts lacked knowledge of species (e.g. taxonomic identification). Interestingly, the knowledge deficient in species identification was not fundamentally different between volunteers and experts (Schulemann-Maier et a. 2018). The authors conclude that experiences and the status of being an expert does not necessarily lead to better identification skills in species; both groups can misidentify species.

Further, Ostrom (2011) highlight the importance of recognizing knowledge as a common good. People hold all kinds of formal and informal knowledge, but only if this knowledge is freely available and accessible, can it be used by science, policy and society members.

Also, I found that the achievement of learning and understanding goals in environmental citizen science projects is made difficult due to different types of learners, various motivations for learning, inadequate communication and teaching of biodiversity knowledge as well as various kinds of learning (goal-oriented versus process-oriented learning). Schulte et al. (2019) state that learning about species diversity is made particularly effective by informal settings (e.g. outside a school context) and by mentor-mentee relationships. Moczek et al. (2018) conclude that learning and understanding should focus on subjects of learning in need and on demand. Participants indicated that they specifically needed to improve their theoretical ecological knowledge, research methods, and taxonomic identification (Moczek et al. 2018).

When it comes to achieving the goal of enabling participation, I identified the following challenges identified relevant from a volunteer's perspective: denial of access to participation, concerns about no "real" participation (pseudo-participation), personal restrictions, and mistrust in environmental sciences (Kubicek, Lippa & Westholm 2009, Bundesfreiwilligen Survey 2017). As previously stated, volunteering opportunities are unevenly distributed. Social and personal resources are required to access voluntarism. Most importantly, engagement needs to be compatible with other tasks and obligations such as family or/and work-related responsibilities (Bundesfreiwilligen Survey 2017).

Overall, the most important condition for any kind of cooperation is a trustful relationship. Without trust, no cooperation can take place. Thus, positive and/or negative volunteering experiences affect present and future engagement. Although public mistrust in science is not a novel phenomenon (Braun 1999), this might be still a common barrier for people's interest in science participation.

At this point, I acknowledge that all identified factors lack details related to actors in agricultural landscapes. Both, the approach of ecological and environmental citizen science, and specifically volunteer-based monitoring of biodiversity in agricultural landscapes, have only recently been applied in agricultural landscapes. Most recent research in this domain reveals the promises of citizen science as an innovative approach to participation in research (Gavel et al. 2020, Ryan et al. 2018) but less on why farmers or hunters participate or fail to appear in environmental citizen science. Thus, the basis of the indicator development, namely the factors, must be revised, and adopted accordingly with and by the community of practitioners in the future, hand in hand with the development of environmental citizen science and monitoring of biological diversity in agricultural landscapes.

3.5. IDENTIFICATION AND EVALUATION OF ACTIONS TO OVERCOME THE CHALLENGES

Based on the identified factors, I recommend the implementation of six actions (A1-A6) for short- and medium-term for volunteer-based monitoring of biological diversity (Table 2). From the six actions integrated into A2 as educational and learning aspects are integral parts of BioBlitzes and in program-orientated citizen science. From this matrix, three main actions are prioritized for the derivation of qualitative and quantitative indicators. These final actions are: 1) the development of capacities for volunteer-based monitoring of biological diversity, 2) recognition, and appreciation for those involved in these schemes, and 3) development of educational and learning modules about biological diversity monitoring.

actions to overcome the challenges for volunteer participation

	Description of the action	Linkages to identified factors
A1	Implementation of actions to develop capacities for volunteer-based monitoring of biological diversity to establish opportunities for voluntary engagement and participation in ecological and environmental citizen science projects linked to monitoring activities	FP1, FP2, FP3, FP6, FSF1, FSF2, FSF3, FSF5, FAP1, FAP2, FAP4
A2	Development and implementation of event-based citizen science (Bioblitz), project-oriented citizen science (project) and program-oriented citizen science (monitoring) considering target group-specific requirements and anticipated outcomes	FP1, FP4, FP5, FP6, FP8, FBN1, FBD2, FBD3, FSF2, FSF3, FSF4, FKG1, FLU1, FLU2, FAP2, FAP4
A3	Expansion of existing networks of people and groups of people (clubs, associations) as well as establishment of new partnerships between members from academia and volunteers in the field of biodiversity research	FP2, FP4, FP5, FP6, FP9, FBD3, FSF1, FSF2, FSF3, FSF5, FW2, FLU2, FLU3, FAP1, FAP2, FAP4
A4	Development and implementation of educational and learning modules on biological diversity	FP6, FP9, FBD1, FBD2, FBD3, FBD4, FSF6, FKG1, FKG2, FLU1, FLU2, FLV3, FAP4
A5	Development of tools to improve competencies of monitoring methods and species identification and skills in project communication and management	FP7, FBD1, FBD2, FKG1,
A6	Development of recognition and appreciation mechanisms for voluntary work in monitoring biological diversity	FP1, FP4, FP5, FP8, FBD5, FSF1, FSF2, FSF3, FSF4, FAP2

Table 2: Overview of formulated, actions A4 and A5 may be . The right column shows the links to the factors identified in Table 1 (Suppl. Material) based on a coding system.

3.6. SETS OF INDICATORS FOR VOLUNTEER-BASED BIODIVERSITY MONITORING

Personal responsibility and a feeling of "ownership" by all members involved are central to the development of capacities for volunteer-based monitoring. Thus, capacity development is based on appropriate investments in people, facilities, practices, and partnerships. In the process of indicator development, two main questions are taken into consideration: "capacity for what?" and "capacity for whom?" (Mizrahi 2004). Here, I propose the following set of indicators to determine the success of capacity development for volunteer-based monitoring of biological diversity (Richter et al. 2016).

SET 1:
Indicators for the assessment of achieving capacity development

- Number of identified and voluntarily involved actors in a volunteer-based monitoring activity
- Ratio of active and non-active volunteers
- Compliance with actors involved in the schemes on the resources needed for the implementation of the activity
- Level of visibility of processes regarding development of joint visions and action plans Number of supporting resources developed for the design and implementation of monitoring activities
- Number of internal and external communication measures as well as support resources such as guidelines and handouts
- Quality of communication and organisational measures
- Rates of consultations and advices integrated in the scheme
- Level of participation according to project objectives and participants demand
- Number of developed and implemented Citizen Science-based projects
- Extent of evaluations of these projects in respect to scientific results and influences on social, economic, and environmental levels

Recognition and appreciation in and for volunteer engagement are essential variables for motivation and an integral part of planning and implementation of all volunteer-based monitoring schemes. Projects and their results, as well as those involved in the projects, must be made visible and recognizable, both internally and externally. At the individual level, existing networks and established partnerships build opportunities for exchange and getting to know each other. The following set of indicators is proposed for the establishment of a culture of appreciation of voluntary participation in ecological and environmental citizens science as well as for volunteer-based monitoring schemes.

SET 2:
Indicators for the assessment of recognition and appreciation actions

- Number of network meetings, workshops, and opportunities for encounters and exchanges for those involved in the schemes
- Quality of professional interaction with involved actors, e.g. preparation planning for network meetings, appropriate locations, language and target group-specific contents
- Named volunteers (in relation to total number of volunteers) in presentations of the projects, e.g. in media reports, publications, and social networks
- Number of established networks
- Quality of established partnerships and collaborations
- Quality of instruments of recognition

Education and learning are integral parts of ecological and environmental citizen science and are recommended also for volunteer-based monitoring projects. I propose the following indicators to assess the quality and quantity of educational and learning modules about biological diversity in agricultural landscapes.

SET 3:
Indicators for the assessment of educational and learning actions

- Number of educational units with a focus on the concept(s) of biological diversity
- Number of educational units for the knowledge transfer of biological-ecological systems in the context of socio-economic relations
- Quality of educational units
- Number of target group-specific educational units for species identification and learning tools for gaining competencies in monitoring methods
- Number of participants in educational and communication units
- Level of evaluation of education and learning units about applicability and impact

CONCLUSIONS AND NEXT STEPS

The proposed sets of indicators for volunteer-based monitoring are considered as quality assurance features and for the application as tools to qualitatively and quantitatively measure progress and processes in event-based citizen science (e.g., BioBlitz), project- or program-oriented monitoring of biological diversity. Although initially developed for the purpose of application in the context of biodiversity monitoring in agricultural settings, throughout the investigation, it became evident, that a knowledge gap exists regarding volunteer and stakeholder engagement in ecological and environmental citizen science in agricultural landscapes. The practice of citizen science slowly takes place in agricultural settings and much of the potential of citizen science is yet to be explored in the context of agricultural research. It seems inevitable that research about reasons why e.g., farmers and agronomists are motivated or less willing to take part in the recording of pollinator species in comparison to researchers and volunteers (Garratt et al. 2019) is needed. Understanding motives and/or the lack of motivation for participation in citizen science-based monitoring by actors of the agricultural landscapes is vital for the success of any future biodiversity monitoring scheme. As a consequence of the current limited information, the presented indicators are not restricted to agricultural landscapes. They are applicable in a more general context in citizen science-based monitoring activities.

Another caveat of the study relates to the fact that findings from the conference and the literature are predominantly reported from experiences and studies from the global North. Consequently, it needs to be acknowledged that the proposed indicators and actions may generally apply well in the contemporary global North. However, the majority of the world's farmers reside in the global South, in some worlds unique and diverse hotspots of biodiversity. The design of biodiversity monitoring schemes, internationally and globally, will depend on volunteers and stakeholder contributions across the globe. Therefore, it is important to acknowledge that indicators assessing quality and quantity of e.g., capacity building for engagement of volunteers, volunteer commitment, and education and learning outcomes are essential to any biodiversity monitoring scheme, but their development will be impacted by regional, national, and global differences. Thus, it seems appropriate to expand the methods for the development as outlined in this study. This expansion beyond the conventional approach toward participatory approaches may guide future indicator development for biodiversity monitoring schemes in different contexts.

One final important point to highlight as a restriction of this study relates to referred effects of demographic barriers to participation. As highlighted by Pandya (2012) the lack of participation goes beyond demographical variables of age and ethnic imbalance. The imbalance reflects a mixture of mechanistic and structural barriers such as access to areas and restricted mobility and barriers that are created by the disconnection of norms and values of the research community and the underrepresented community (Pandya 2012). Designing citizen-science programs that align with community priorities are suggested to overcome the imbalance of engaged communities in citizen science.

The development of the three sets of indicators, as outlined here, can be considered a conventional approach in program or project evaluation. In recent years, conventional program evaluations have been complemented by participatory evaluation. The aim of this was to gain wider ownership, create shared responsibility, and become "ethically sound since it involves those who are most directly affected by its outcomes" (Campilan 2000, p.5).

In general, an effective evaluation consists of a mixed-evaluation approach, including conventional evaluation from outsiders as well as participatory evaluation by insiders. This means, it complements the generic goals of program evaluation and serves the needs of project initiators and funders. The next step towards such an integrated mixed-evaluation approach requires the development of indicators for participatory evaluation to assess to what extent capacity, recognition, and appreciation as well as educational and learning goals were achieved in volunteer-based biodiversity monitoring (Zukoski & Luluquisen 2002). The questions outlined before (see section 1.2) may also guide the processes in participatory evaluation. Once participatory-developed indicators for the assessment of specific volunteer-based biodiversity monitoring are developed on the basis of participatory evaluation principles, all stakeholders can negotiate the indicators. The sets of indicators should be subject to reflection by both the scientific community, and the practitioner's community regarding their suitability for real-life conditions, reliability, and meaningfulness.

Any integrated citizen science-based monitoring requires a permanent assessment whether the needs of the participants are being met. As highlighted by West & Pateman (2016) evaluation and monitoring are essential part of citizen science to assess e. g. the effectiveness of recruitment and retention strategies. This assessment ideally covers many stages of the participants involvement; starting with the decisions to take part in a project to the question of sustained involvement.

Key to success of the schemes is likely the integration of knowledge about the desire to take part as a combination of individual and organization attributes (Penner 2002) and their interlinkages with volunteers' motivation and retention and communication strategies (See et al. 2016, Dickinson et al. 2012). Hobbs and White (2012) identified three main settings for participants' engagement in environmental citizen science. Most importantly for participants engagements are: being aware that the opportunity for taking part in a project exists, the activity is of relevance to the person, and that the person is motivated. Design of the schemes and recruitment strategies need to take this into consideration to succeed with the project.

Communication, as an essential aspect of any citizen science, secures the processes of recruitment and retention of participants (Hecker et al. 2018). Overall, communication enables participants to be and stay informed about the schemes, be and feel connected to members of the schemes, and be empowered as a speaker of issues of concern. Interestingly, the communication of the project results and regular communication on the contributions made by the participants are more appreciated by the participants than any kind of reward (Alender 2016) and secure engagement (See et al. 2016). This is explicitly the case when participants are intrinsically motivated.

In the end, communication affects and is affected by many factors influencing participants' decisions to take part in citizen science at the same time at addressing the needs of both; the participants and the initiators of a scheme. Thus, competencies in communication are inevitable to meet on equal footing.

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KEYWORDS
monitoring, indicators, volunteer perspectives, quality assurance

DOCUMENTING AND ASSESSING OPEN INNOVATION: CO-CREATION OF AN OPEN DATA MODEL FOR SURGICAL TRAINING

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PRAXIS REPORT

ABSTRACT

Challenge competitions have recently resurged for promoting open innovation in areas where markets fail to provide incentives, such as the Sustainable Development Goals (SDGs). Challenges call for the general public to contribute novel solutions to a well-defined problem, in exchange for prizes, credentials and the promise of further development of selected solutions. The aim of this paper is to report on the development of an open and collaborative data model to document and evaluate innovations in the context of a challenge competition, while also being compatible with the work of other open source communities to validate and improve them. By reusing open documentation standards and embedding them into a semantic collaborative platform, the model aimed to be flexible enough to respond to the evaluation needs of the project organisers and self-assessment for participants. We expect our experience provides insights on the potential of semantic, collaborative platforms and standards for increasing the impact of innovations towards the SDGs.

INTRODUCTION

Since the 2000s, organisations in the public and private sector have been increasingly experimenting with opening their innovation processes to external collaborators. Examples include firms developing kits to incentivize user-led innovation (von Hippel, 2005; Boggels et al., 2018; Redlich et al., 2019), or academic research projects seizing the power of crowds to tackle "wicked problems" (Majchrzak & Arvind, 2020). Within this context, challenge competitions or innovation prizes are initiatives that invite the general public to propose novel solutions to a well-defined problem, in exchange for credentials, monetary prizes and the promise of further development (Williams, 2012; Zelmer et al., 2017). These prizes and challenges aim to promote innovation in areas that are valuable for society, especially where market failures do not generate enough stimuli (Brunt et al., 2012).

Digital platforms have incentivised a recent upsurge of prizes in areas ranging from health (Wilson & Palriwala, 2011) to conservation ecology (Conservation X, 2022), all of which fit more broadly into the Sustainable Development Goals (OpenSeventeen, 2022), opening new opportunities for increasing the impact of innovations. For example, participants could document their innovations openly online and learn from their peers' developments, adding a layer of transparency to the challenge, and allowing solutions to be reused outside its scope. However, these opportunities remain mostly unexplored by challenge organisers who tend to reproduce the conventional model into the online territory.

Online documentation of innovations is a practice at the core of the maker, open design and open hardware movements (Bonvoisin et al., 2017), albeit a complex and time-consuming task. Researchers in these fields have examined online repositories of documentation to understand collaboration dynamics and motivations (Schroer & Hertel, 2009; Morreale et al., 2017; Bonvoisin et al., 2018) and to propose multiple frameworks to evaluate the "openness" of projects based on its project documentation (Bonvoisin & Mies, 2018; OSHWA, 2016). These metrics usually evaluate how reproducible a design is, meaning how easy it is for an independent party to recreate the designs based solely on the project documentation. These instances of evaluation are often implemented asynchronously once documentation is "complete". However, due to the multiple possible domains of application, these tools are not able to fully capture context-dependent information that is crucial for evaluating innovations.

This paper reports on the community-led design of a data model used to evaluate innovations in the context of a challenge competition. The evaluation was two-folded: participants compared their open documentation against the judgement criteria to self-assess their progress throughout the innovation process. At the same time, a judging panel used it as a completion checklist to select outstanding innovations. The design of the data model is based on a documentation standard developed by the open hardware community, and was adapted to the specific knowledge domain of the challenge through participatory workshops with domain experts. As a result, by using a Research through Design strategy (Menichinelli et al., 2021), this data model was flexible enough to respond to the documentation and evaluation needs of the project organisers and participants. Moreover, by being embedded into a wiki or collaborative platform, it allowed participants to see the evaluation criteria in action and self-assess their work throughout the challenge in an interactive way.

The paper begins by (1) introducing the Global Surgical Training Challenge as the implementation context. Next, it describes (2) the methods used to develop the platform and collect assessment data, and (3) the results of the implementation process. Section (4) discusses the evaluation processes mediated by the platform, and the use of wiki-based platforms for documenting and evaluating innovations in challenge competitions. Finally, we identify the (5) challenges and limitations of this approach, as well as future work needed.

1. THE GLOBAL SURGICAL TRAINING CHALLENGE

The Global Surgical Training Challenge (GSTC)[1] is a competition aiming to make simulation-based surgical training accessible worldwide through low-cost, open-source training modules (Appropedia, 2021). Participants around the world are invited to submit innovations that improve the remote learning of surgical skills, with a focus on Low- and Middle-Income Countries (LMIC). The initiative is organised by the Intuitive Foundation —a U.S.-based nonprofit organisation—, in collaboration with NESTA Challenges, the Royal College of Surgeons Ireland, MIT Solve, and the Appropedia Foundation.

The challenge was designed to engage a broad range of innovators, including education specialists, surgeons, midwives and nurses with experience working in resource-constrained settings; engineers and software and game developers; artists, medical illustrators, and designers. The awards are granted in phases: Discovery Awards of up to $200,000 to support prototype development, $500,000 awarded at the Finalist stage to advance model development, and $1 million to selected finalists. The Finalist Award teams have representatives from across multiple continents, but are focused on surgical training needs in LMICs, including Ethiopia, Guatemala, and Nigeria. They represent a variety of surgical specialties, including obstetrics, trauma, orthopaedics, and reconstructive surgery.

The GSTC constitutes an interesting case study of challenge competitions that strive towards the Sustainable Development Goals (SDGs). Aligned with SDG 17, building partnerships for the goals, the challenge aims to foster innovation through open collaboration and knowledge sharing between multiple stakeholders in civil society (Howaldt, 2021; Jha et al., 2016). By focusing on innovations that enable training in surgical skills, the challenge addresses two other SDGs: health and wellbeing (SDG 03) and quality education (SDG 04). Quality education, by establishing an open knowledge co-creation model that lowers access barriers for participants in LMICs. Health and wellbeing, because the ultimate goal of the challenge is to promote greater access to healthcare in under-served areas. Enabling more people to be trained in surgical skills where they are needed the most (target 3.8), but where conventional approaches to innovation can't find market incentives (Natera et al., 2019).

Similar to other innovation prizes, the GSTC opens the space to explore new solutions to a problem. However, it also aims to open the innovation processes to the general public: all submissions must make their innovations open source and reproducible for other parties after the competition. To achieve this, participants are encouraged to document their prototypes in Appropedia, an appropriate technology wiki that hosts open designs since 2005[2].

In the context of GSTC, the selection criteria for best innovations goes beyond examining the core proposals; criteria include the outlook of potential uptake, the chances of end users successfully adopting them. This poses the challenge to consider how they will not only be laid out for judges during the competition, but also communicated across different communities in new contexts, using multiple content formats, thus ensuring reproducibility and that learners will acquire and use these skills. For example, assessing how the innovation facilitates its diffusion by encouraging engagement of physicians through different means (Rogers, 1995).

For this reason, challenge organisers, mentors and members of an interdisciplinary judging panel use public documentation on Appropedia as the entry point to evaluate the novelty and fit of these innovations. The rationale behind this decision is that the same material will be used by future learners and practitioners, as they use these innovations. Participants would also be able to understand what is expected from the documentation to self-assess their progress during the life of the challenge, especially given the inability of participants to coordinate in person due to the COVID-19 pandemic.

2. METHODS

To build a platform that allows documentation and evaluation of innovations we started by defining its underlying data model (or domain ontology). In information science, ontologies are "a means to formally model the structure of a system, i.e., the relevant entities and relations that emerge from its observation, and which are useful to our purposes" (Guarino et al., 2009).

To design a domain ontology, it is therefore necessary to arrive at an agreement of what will be represented. To do this, we followed the process described by Brusa et al. (2008) based on Gruninger & Fox (1995) and Gómez-Pérez et al. (2004). This methodology consists of three main stages: the ontology specification, concretisation, and implementation. All activities took place between June and September 2020 with the intervention of the actors described in Table 1.

Table 1. List of participants (roles), stages in which they participated and denomination in the article.

Participant	Participated in stage	Denomination
Domain expert A	Specification, concretisation, implementation	Developer team
Domain expert B	Specification, concretisation, implementation	Developer team
Appropedia Foundation representative	Specification, concretisation, implementation	Developer team
Intuitive Foundation representative A	Specification, concretisation, implementation	Project owner
Intuitive Foundation representative B	Specification, concretisation, implementation	Project owner
Medical field experts (3 participants)	Specification	Consulted experts
Representatives of challenge teams (13 participants)	Specification, concretisation, implementation	Innovators

1 https://globalsurgicaltraining.challenges.org
2 https://www.appropedia.org/

All activities took place between June and September 2020 with the intervention of the following actors:

- Specification: the developer team defined the goal and scope of the ontology in collaboration with the project owners. This was done by agreeing on scenarios where the ontology will be used and establishing competency questions that the ontology must be able to respond to.
- Concretisation: the developer team used the specification outputs combined with literature review and consulted expert assessment to produce a first draft of the ontology. This included main concepts, relations between them and data constraints. After multiple iterations with the project owners, the final version was formalised in a standard graphic representation (UML).
- Implementation: the developer team produced a machine-readable version of the ontology in OWL format using the software Protégé; its internal consistency was verified using the Protégé reasoner HermiT 1.4.3 tool. The team validated the ontology with the project owners in a dedicated workshop. At this stage the team embedded the ontology into a WikiMedia instance, to turn it into an interactive, open and collaborative platform.

The data sources for designing the ontology included:

A. Workshops and informal conversations with project owners
B. Analysis of data collected by project owners
C. Literature review of open ontologies on education (Chung and Kim, 2016; Katis et al., 2018) and open hardware (Open Know-How standard , Bonvoisin & Mies, 2018)
D. Data on participants' use of the platform, collected from the MediaWiki instance

3. RESULTS

ONTOLOGY SPECIFICATION

The goal and scope of the ontology were defined based on meetings between the developer team and the challenge organisers. These meetings were guided by three questions: (a) who are the users and what are the settings for the training modules; (b) what does the project owners define as a complete documentation, (c) what information is required by the mentors and judging panel to assess the modules. These questions allowed the developer team to define the scenarios and competency questions of the ontology.

Before the first meeting, the developer team was provided with a graphic artefact that reflected the GSTC expectations and evaluation criteria (Figure 1), and a database of "lessons" that the innovators could use as inputs. As seen in Figure 1, the project owners had previously agreed on a visual representation of the model with boxes for different kinds of skills and tools, which unintentionally aided in the definition of classes and subclasses for the data model. This information was useful to understand the expectations of the project owners. This design provided by the project owners was useful to discuss what they understood

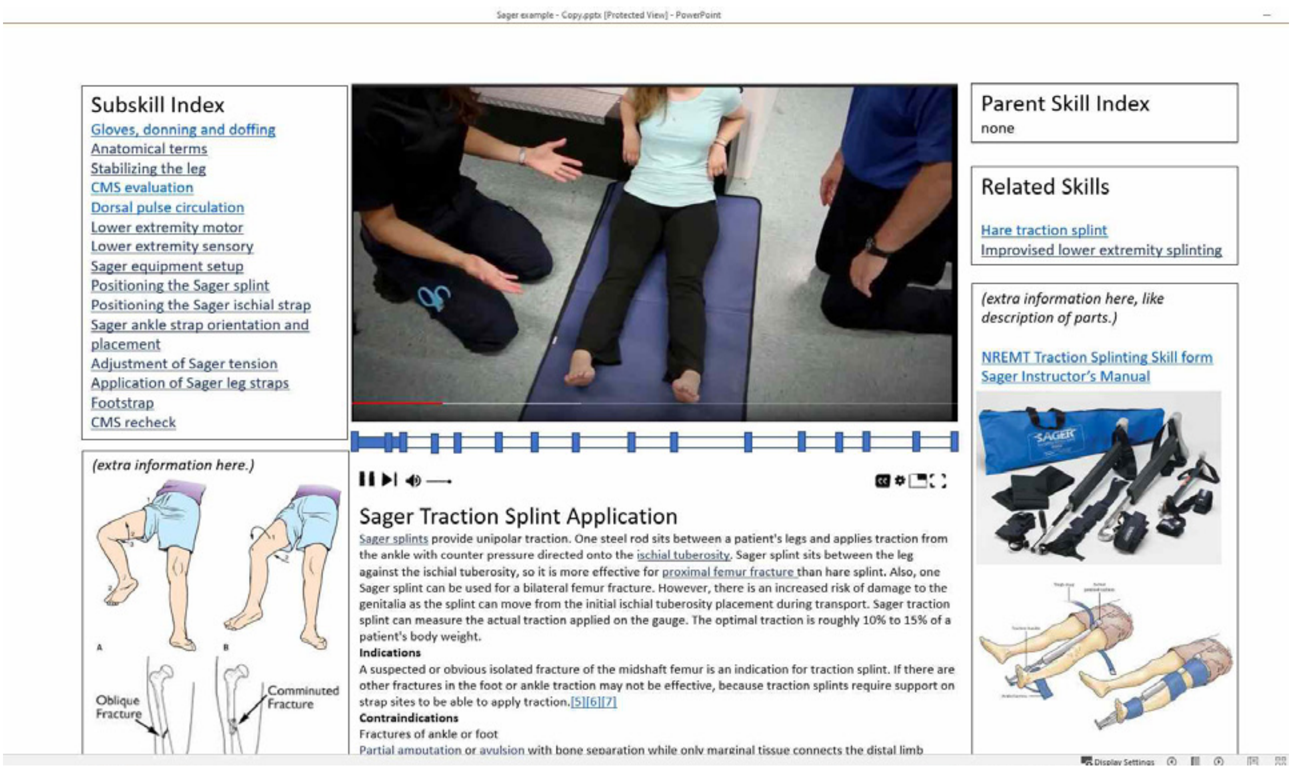

Figure 1 Graphic representation of the expectations of GSTC organisers for projects' documentation (source: Intuitive Foundation).

3 https://www.internetofproduction.org/open-know-how

as a "skill", and making the decision of turning the skill into the main hierarchy to work with.

Once the data model was rolled out, the challenge innovators were invited to document their innovations on Appropedia using various formats that included hardware and software documentation, text materials, and self-assessment components, with a special emphasis on audio-visual materials. Project owners also conveyed the importance of hierarchic relationships between training modules, and how those sequences would determine how users navigate the platform. Based on these inputs, the developer team drafted a proposal that was iterated with the project owners and consulted experts; requirements were recorded after each workshop.

After this initial exploration, the developer team facilitated a workshop session with the project owners and consulted experts to envision the future platform from its users' perspective. This resulted in the identification of four main motivating scenarios. Following design thinking techniques, the facilitation process led the organisers to think of the data model in relation to its users and their particular goals, actions, pains and gains. The decision to use design-thinking techniques was based on the experience of the development team and familiarity of the project owners with this approach. Figure 2 shows the instrument used to collect data, in collaboration with the session participants, who were able to modify these notes during the session. After the session, the developer team condensed the insights into a series of four motivating scenarios (Table 2, see additional materials, pp. 91) and their related competency questions (Table 3, see additional materials, pp. 92).

The goal of the data model was *"to represent the set of entities and its relations involved in the process of creating and delivering self-assessed medical training"*. The design team identified a list of use cases:

- Scenario 1: undergraduate students who are acquiring new practical skills.
- Scenario 2: professors and professionals with expertise who wish to learn new skills as part of their professional development.

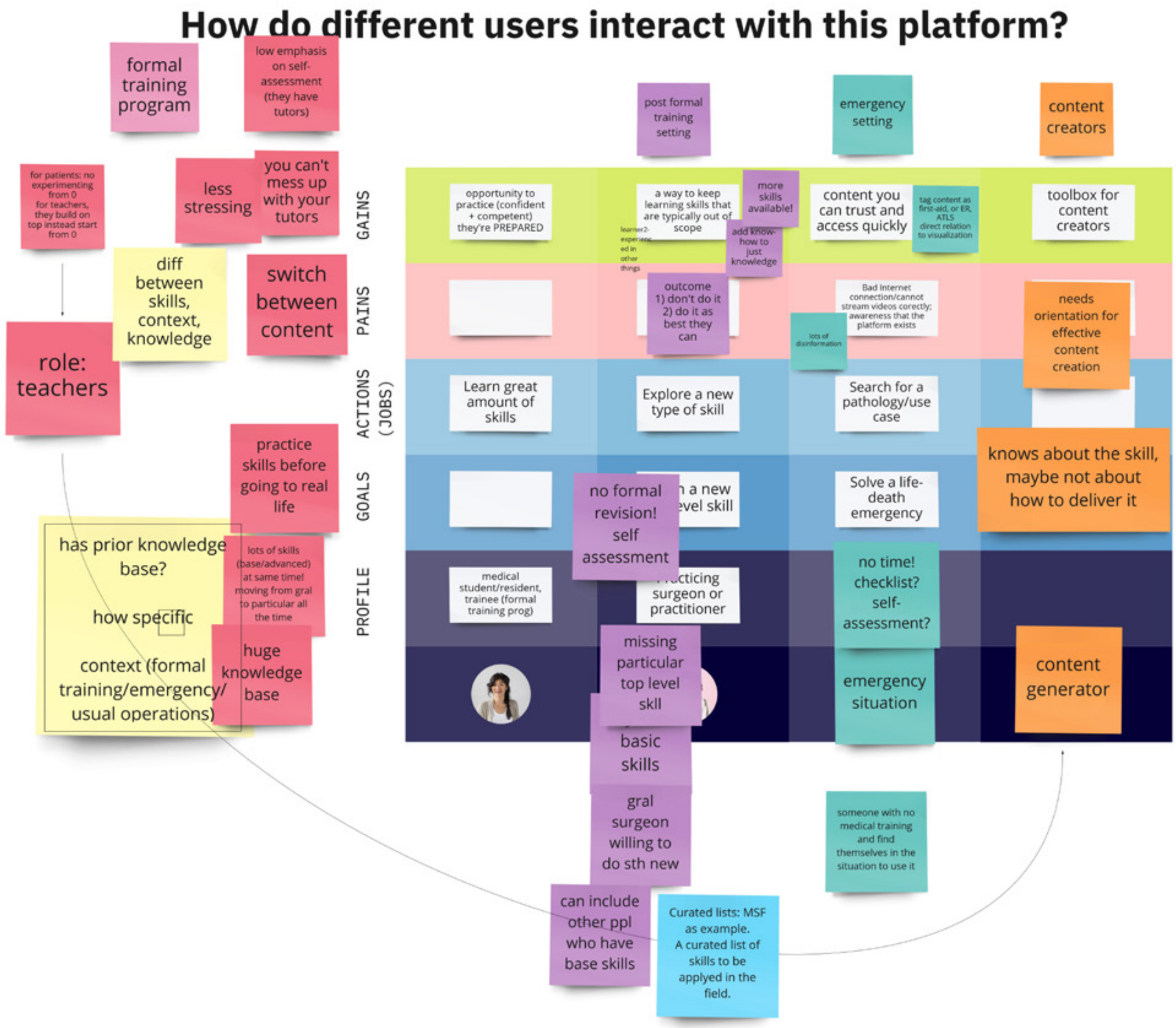

Figure 2 Notes from the session with GSTC organisers focused on envisioning users and their interaction with the platform

- Scenario 3: individuals in emergency situations
- Scenario 4: medical professionals in low-income remote areas.

As a result, the scope of the ontology was limited to scenarios 1, 2 and 4 to prioritize the most relevant use cases for the GSTC modules. Scenario 3 may be included in a future stage after running a pilot program using this version of the ontology.

ONTOLOGY CONCRETIZATION

The competency questions and scenarios were used by the developer team to understand which the most relevant concepts were to be included in the ontology, and propose an initial hierarchy of classes and subclasses. To do this, we reused open ontologies on education and open hardware, combining them with the specific medical theme of the challenge.

To model classes and subclasses we followed the priorities that emerged during the workshops: a) hierarchies within the training material (parent skill/sub skill), b) resources required for training (equipment), c) metadata for findability (body part) and module-specific information (hours, roles), d) pointers to external resources on Appropedia or external URIs to resources such as software, platforms and other assets provided as part of the modules.

After three iterations, the developer team and project owners defined a list of terms that represent the most important entities in the domain and their relations. These are shown in Figure 3, which lists the classes and subclass (<MedicalSkill>) that structure the model. As a result of the agreement, a significant component of the ontology is audio-visual material (Media class) and its annotations (MediaAnnotation).

Graphical representations were always useful to reach agreements during the design process. At this stage, the developer team produced a UML graphic representation showing the classes contained in the ontology and their relationships (Figure 4, see additional materials, pp. 92). UML or Unified Modeling Language is a standard notation consisting of an integrated set of diagrams, considered best practice in software engineering. It provides a way to visualize the design of a system, enhancing communication with users, who can visually understand the system components and their interactions at a glance. However, these representations lack interactivity. This limits the process of obtaining feedback only to synchronous instances of collaboration (e.g., workshops). For this reason, at this stage of the process the developer team decided to embed the ontology in a MediaWiki instance (Figure 5, see additional materials, pp. 93).

Class name
Course
Intervention
Material
Media
MediaAnnotation
Syllabus
Tool
Skill
↳Medical Skill

Figure 3 Classes represented in the GSTC ontology

ONTOLOGY IMPLEMENTATION

TThe ontology was formally designed and verified using the Protégé reasoner HermiT 1.4.3 tool without any detected inconsistencies.[4] To graphically verify the implementation versus the agreed UML diagram, we produced a visualisation using WebVOWL (Figure 6).[5] This diagram, representing classes (circles) and properties (rectangles), resulted in a useful and more user-friendly way to communicate the final design to the project owners.

To validate that the ontology is indeed representing the domain for which it was created, we transformed the competency questions into queries in MediaWiki. Figure 7 shows the results of the MediaWiki search engine once the competency question is translated to query language. These translations were used during a simulation workshop with the project owners and consulted experts, after loading a test dataset provided by the project owners themselves. In this session, attendees acted as future learners of each scenario and tried to achieve their goals in real time using the platform. In this way, they were able to test the functioning of the ontology by themselves and provide further feedback.

The development team gathered and systematised all the feedback from the project owners and consulted experts on each competency question. After the session, all material was reviewed and requests for changes were categorised either as "in-scope" and "future work". In-scope changes were implemented in a new iteration, while those recommendations out of scope were documented for future iterations. Future work includes two competency questions from scenario 1 (undergrad learning support), and one from scenario 4 (creation of audio-visual training material). These comprise features allowing students to provide feedback on the content of a Skill page, allowing them to use the platform to self-assess learning goals, and enabling contributors to create content that is not considered a Skill. Once the ontology was approved by the project owners, the Appropedia Foundation used it to build dedicated materials to teach how to document innovations.[6]

USE OF THE DATA MODEL FOR EVALUATION

As an outcome, innovators documented 13 innovations in the platform. Asynchronous feedback was provided during the process by using the data model to show the progress of documentation and missing elements. This included the detection of *red links*[7] or missing parameters as

4 It can be accessed in OWL format at https://github.com/cientopolis/appropedia-surgery.

5 This visualisation can be accessed at https://service.tib.eu/webvowl/#iri=https://raw.githubusercontent.com/cientopolis/appropedia-surgery/master/appropedia-skills.owl.

6 A video tutorial explaining the process can be found at https://www.appropedia.org/File:Appropedia_workshop_video.mp4.

7 A red link is a term for non-existent page links on a MediaWiki instance such as Appropedia or Wikipedia. Red links are used as content building tools by collaborative communities. https://www.mediawiki.org/wiki/Manual:Glossary#Red_link

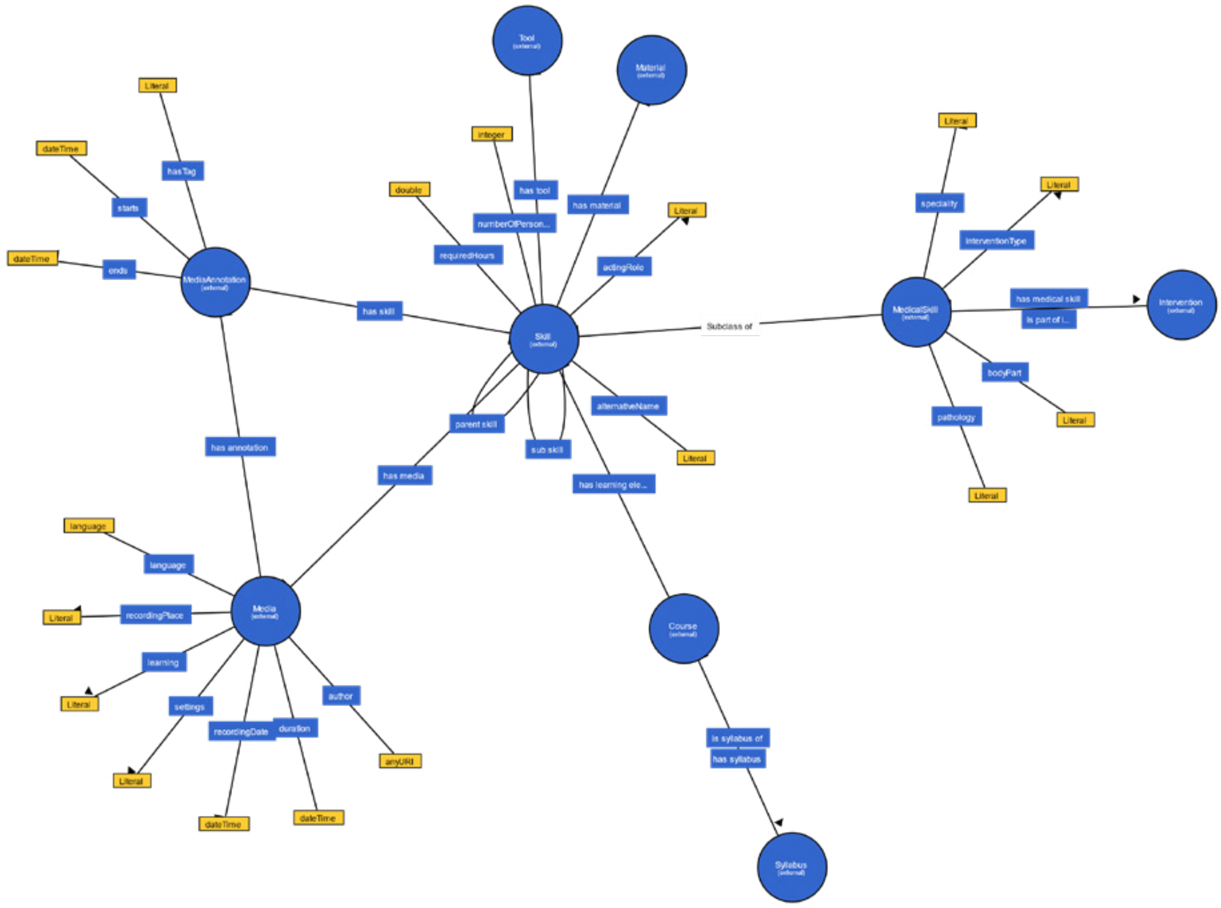

Figure 7 WebVOWL diagram representing classes and properties contained in the ontology

C. I want to access those skills that belong to a specific domain that I'm not an expert in

edit edit source

```
{{#ask:
[[Category:Medical skills]][[Pathology::Contusion]]
|format = ul
}}
```

- Alertness and Orientation Assessment (A&O)
- Hemorrhage Control
- Primary Assessment
- Sager Traction Splint Application
- Trauma Patient Assessment

Figure 7 example of competency question and its resolution, implemented in MediaWiki

indicators of incomplete information, the presence or absence of multimedia elements, and quality of text content. This information was valuable at the final stages of the challenge for the project owners, who used the public documentation in the platform as the main source of information during the judging process. The ontology allowed the judges to identify the fields that innovators planned to document but did not complete, as well as some that were left completely unused, which will be considered in future revisions of the data model. This was done through the recognition of red links, which showed which pages for each module had been planned but had not been created at the time of assessment. Innovators used elements of the model in the expected order of importance, prioritising the module structure (parent skills and sub skills) to other classes. Figure 8 (see additional materials, pp. 93) shows an example of the documentation progress for one of the most visited skills.

4. DISCUSSION

The user-centred, open, and collaborative approach that allowed the development of the platform reported different benefits to the challenge stakeholders. On the one hand, project owners increased the transparency of selection criteria and provided innovators with concrete tools to guide their documentation processes. This generated trust in the process and facilitated the judging process. Moreover, the version control feature of the platform provided access to a detailed archive of the competition and how innovators engaged in it. This is useful information for the project owners, who aim to improve future editions of the initiative based on these insights.

Project owners were able to support the innovators' journey by providing early training on how to use the platform for documentation, and closely tracking the documentation progress by using the ontology to detect any issues. This resulted in the development of new training sessions; participants also provided input on their experiences with the platform during the challenge. These were incorporated as feedback for the next version of the data model.

By reusing available open vocabularies for developing the data model, the innovations documented in the context of the GSTC are now compatible with those in the open hardware community. This increases the possibility of impact for these learning modules, as they can now be found and reused by people outside the scope of the challenge. Observing and measuring this impact is part of the work in progress with the Appropedia Foundation, in a second stage of the project. Future work on this aspect includes flagging complete GSTC projects as "pre-approved" for certification paths by using the already-existing data model, as well as developing automatic validation tools for innovators to self-assess their progress.

Innovators went through an initial steep learning curve for understanding how to document their innovations in the platform, as it was noted during screen recordings and through personal feedback gathered by the developer team. However, multiple iterations on the visual design of the platform lowered this entry barrier. Initially, project owners had concerns about innovators being "too inspired" by other teams' ideas if these were openly accessible. However, the possibility to see what fellow innovators were doing in real time resulted in participants investing more effort into enhancing their own documentation quality. Project documentation can now be used as an innovation diffusion channel by innovators to potentially attract new collaboration outside the challenge.

Platforms like MediaWiki provide interesting features for challenge competitions. Innovators were able to document their innovations in different formats: videos, images, instructions, external links, annotations. The semantic features of MediaWiki turn all these pieces of information into searchable content, regardless of the original hosting platform. As a result, documentation becomes a living instrument that can be accessed through different pathways. For the GSTC, training modules can be found by search parameters such as: tools used, body parts affected, presence of audio-visual content, location in the general curriculum, and many other fields. By using red links as a checklist, project owners were able to quickly identify incomplete sections of their training modules and respond accordingly.

Using an open data model as a tool for evaluation enables conversations among the stakeholders (project owners, innovators and even the challenge judges) that would not happen otherwise. The process of defining criteria and the tracking of how these are fulfilled are opened to discussion and examination; they can also be contested. Moreover, these become flexible to better accommodate the specific demands of the participants. Working with project owners and innovators on the ontology at the beginning of a project is a powerful exercise to capture expectations, agreements, and motivations early in the participatory process. As a result, it builds a baseline against which participants can later evaluate project performance. It is also a powerful tool for project owners, who can contrast their initial expectations with what innovators bring to the challenge, contextualising evaluation.

Using semantic tools on MediaWiki allows for these data models to evolve during the design phases of these challenges, as these data models are used by innovators, or by gathering user feedback at the end. Furthermore, version control ensures that agreements captured in different project stages can be easily accessed at any point in time; the interactive features of the wiki facilitate the design of workshops for capturing feedback. Although it was not planned for this particular iteration, changes to these models can be integrated to existing content on the platform without many of the difficulties posed by other platforms. This can help new and existing stakeholders to define and assess what should be viewed as innovative as these definitions and requirements evolve over time.

5. CONCLUSIONS AND FUTURE WORK

We have described the process of developing a user-centred, open and collaborative wiki-based ontology for documenting innovations in a challenge competition. We consider this first iteration a proof of concept that can be further adapted to other participatory projects and knowledge domains. To increase its uptake, the ontology is designed in a modular way that allows replacing or adding domain-specific knowledge in an accessible way. For example, a challenge or citizen science project on air pollution can extend the model by replacing the class <MedicalSkill> with an air pollution class and its relevant properties.

The model can be used as a tool to implement knowledge co-creation processes in citizen science projects. The wiki interactive features make it a useful platform for facilitating both in-person and remote workshops; the open and collaborative aspects of the model can increase trust and engagement of participants. In-person events such as hackathons or hardware residencies can make use of the platform to document the progress of participants towards the proposed solutions and continue work online after the event. In the case of remote sessions, the platform serves as a one-point hub for organising, running and evaluating the engagement of participants, e.g. by monitoring their work over time using the platform's version control tool. The media class of the ontology can be particularly useful for data collection activities in citizen science projects, allowing participants to share and collaboratively annotate each other's videos, sounds or images. The model provides a framework for standardising both material and non-material knowledge products in participatory research and innovation, which can be used to facilitate transfer of skills between participants. Moreover, documenting knowledge in a semantic platform increases its findability, allowing for multiple search criteria according to diverse needs.

Reusing available ontologies provides a point of connection with the communities responsible for their development, enabling interoperability and opening opportunities for future collaboration. Communities with an explicit open-source ethos can find the model useful to increase transparency and contribution upstream the innovation process. In projects where openness is not a goal, a relevant motivation for uptake is to make innovators reflect on their design assumptions and expose these to their users and contributors.

The ontology can be considered a tool for building more complex, community-based open educational resources (Downes, 2007; Tlili et al., 2020). The use of open licences and the possibility of engaging content creators in multiple settings presents advantages for fostering situated learning and innovation processes. Participants thus can use the model to self-assess their experience in challenges or other citizen science projects. In the case of GSTC, innovators were introduced to the evaluation criteria at the beginning of the competition, which outlined the expectations in terms of completeness and quality and helped them self-assess their work in an interactive manner.

Innovators with different levels of expertise were able to contribute to the documentation process according to their capabilities and interests. The ontology guided their learning process so they could incrementally enhance their documentation, while observing how others were doing it. However promising, it is necessary to consider that wiki-based learning processes may impose participation barriers for some groups (Kear et al., 2016; Biasutti, 2017). Facilitation processes led by project owners are necessary to overcome these barriers and promote the emergence of online communities of practice that increase the quality of knowledge products in citizen science projects.

Since 2020, the data model was formally used in the GSTC competition[8]. The innovators developed the learning modules and used the skills ontology as a completion guide to prepare their submission. The judging panel used it to identify the required elements and announced the four finalists of the competition. The outputs of the competition will be tested with a more thorough methodology in other countries which will reproduce the modules (physical devices, software, educational materials) using the documentation described by the ontology[9]. The model of ontology-based skill training will be used for new surgical training materials with the same partners, but also for other types of materials such as practical guides and community mapping by other institutions. The Appropedia Foundation is working on the future development of the model to include competency questions that were originally out of scope. These are focused on features for participants: improving self-assessment workflows, providing feedback between peers, creating content beyond the proposed formats. Other future work will include updating the data model to reflect better the communication needs of communities and interactive feedback tools for users.

We expect our experience provides useful insights in two ways. First, by showing the potential of semantic platforms for sustainably documenting and evaluating challenge competitions. Second, by highlighting how open documentation can increase the impact of challenges and citizen science projects (and its evaluation). We understand that connecting the valuable ongoing work of different communities is critical towards global challenges, such as the SDGs agenda. We expect our contribution is a first step towards greater collaboration and interoperability. Future research is necessary on the perceptions of users of the platform, on identifying access barriers for underrepresented groups and on criteria for adapting the model to domains outside medical training.

8 https://globalsurgicaltraining.challenges.org
9 https://www.youtube.com/watch?v=ZZFS7YaXOaA

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KEYWORDS: innovation prizes, surgery, remote learning, collaboration, open source

ADDITIONAL MATERIALS

Table 2: Motivating scenarios identified through the co-design process, including actors involved, requirements, sequence of actions and main problems for each one. Available at https://zenodo.org/record/6607508

Table 2. Motivating scenarios identified through the co-design process, including actors involved, requirements, sequence of actions and main problems for each one. Available at https://zenodo.org/record/6607508

Scenario	Name	Description	Site	Actors	Requirements	Normal sequence	Exceptions	Main problems
1	Undergrad learning support	Tasks necessary to access online video material covering a diversity of necessary skills in medicine practice	At home, self managed practice	Medicine students aiming to gain practice	Prior knowledge base (specific terminology, curriculum)	1. Student logs into platform	Students use the platform outside of a course, for example, as reinforcement to their in-person education.	Missing skill
						2. Student searches available skills following different criteria		
						a. Curriculum structure		
						b. Pathology		
						c. Other		
						3. Student selects skill of interest		
			At home, guided e-learning	Teachers working on e-learning	Understanding of platform dynamics	4. Student watches the video		Missing video
						5. Student observes annotations		
						6. (Optional) Student edits or adds annotations		
						7. Student marks skill as complete		
						8. Teachers review progress		
2	Continuous learning for professionals	Access to highly specific training material for professionals in need of updating skills or gaining new ones	At work (hospital, academic institution)	Physicians working in hospitals	Prior knowledge base (specific terminology, curriculum)	1. Health professional logs into platform	None detected	Missing skill
						2. Health professional searches for specific skill or set of skills, following criteria of:		
						a. Specialty		
				Physicians working in remote, low-resource locations	Prior training in medicine practice	b. Pathology		
						3. Required infrastructure		
						4. Health professional finds and selects skill of interest		
			At field site	Paramedics	Understanding of platform dynamics	5. Health professional watches video		Missing video
						6. Health professional observes annotations		
				Nurses		7. (Optional) Health professional edits or adds annotations from local practice		
						8. Health professional finds related skills: same specialty & similar infra		
						9. Health professional completes self-assessment		
3	Emergency training for non-professionals	Access to vital training skills for addressing an emergency situation or provide preventive emergency training	Different locations (home, work, etc)	General public, non-physicians	Understanding of platform dynamics	1. Prof logs into platform	None detected	Short time
						2. Prof searches for missing skills following criteria of:		
						a. Specialty		
						b. Pathology		Poor internet connection
						c. Common ER situations		
						3. User finds and selects skill of interest		
						4. User watches video		Lack of medical vocabulary
						5. User observes annotations		
						6. (Optional) user contributes annotations based on their personal implementation		Lack of feedback
						a. Required infrastructure		
						b. Context		Trust in content
						c. Missing info		
4	Creation of audiovisual training material	A toolbox for content creators willing to upload audiovisual material to the platform	At home	Professors	Understanding of platform dynamics	1. User logs into platform	None detected	Lack of knowledge on successful video creation
						2. User searches for specific skill following criteria of:		
						a. Body part		
						b. Common ER situations		
			At university	MDs		3. User finds and selects skill of interest		
						4. User watches video		
			At hospital	Other education professionals		5. User observes annotations		
						6. (Afterwards) user leaves annotations on implementation, e.g. required infrastructure or context.		

Table 3: Competency questions for each of the four scenarios identified, available at https://zenodo.org/record/6607508

Scenario	Competency question
1	Which are the skills that are part of this syllabus or unit?
	Which skills do I need to learn first before learning this one?
	How much learning time does this skill demand?
	Which tools and materials are needed for this skill?
	Which tools and materials are needed for this course?
2	How can I find skills that can be useful in a rural setting (only 1 doctor + assistant) or in a team (+2)?
	How can I find videos in my language?
	How can I find skills for a knowledge domain that Iâ€™m not an expert in?
3	What to do if someone has traumatism in this particular body part?
	Which tools do I need to help someone who has a specific problem (e.g. deep cut)?
	What skills can be useful for one person in an emergency context?
4	Which skills are missing videos?
	Which videos are good quality and why?
	Which part of the curriculum is most demanded by students?

Figure 4: UML representation of the ontology classes and relationships between them

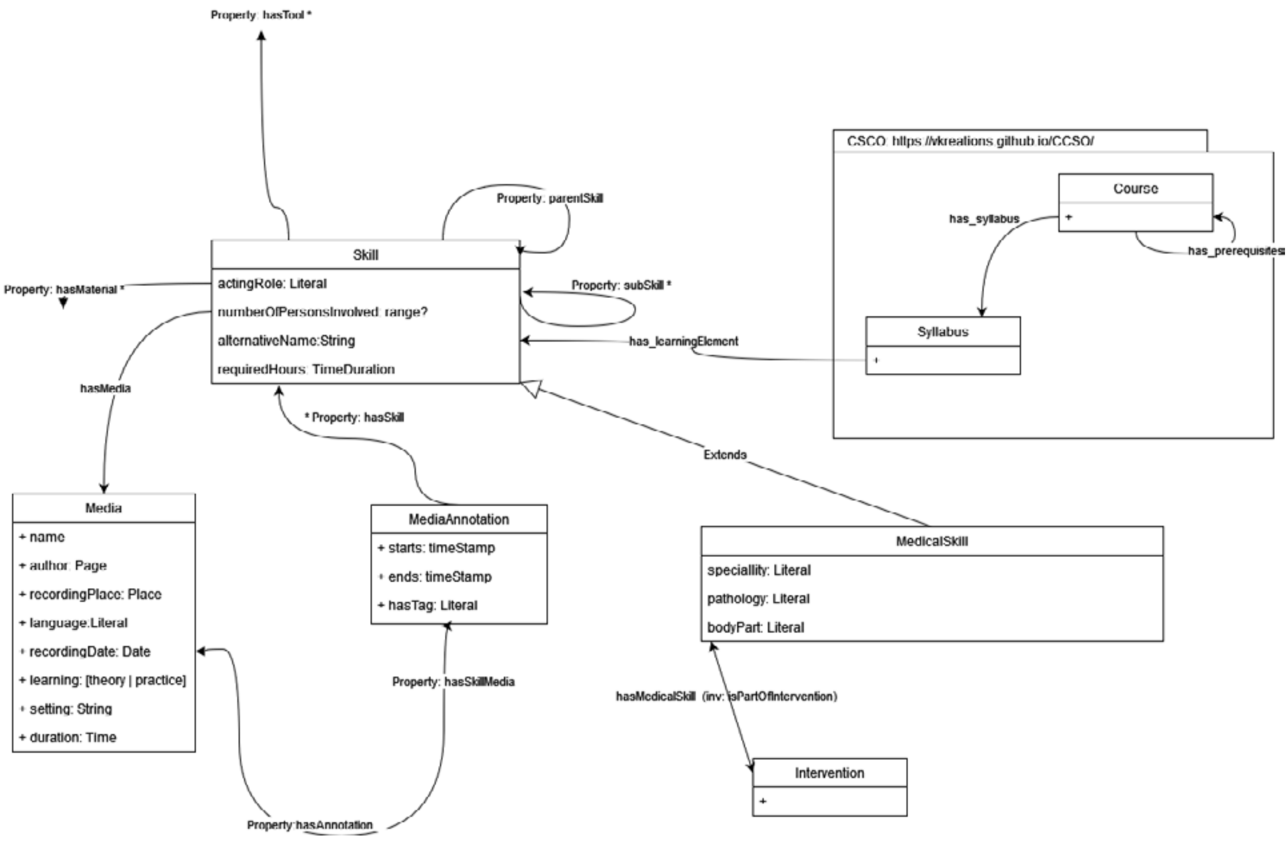


Figure 5: Visualization of the ontology embedded in the MediaWiki instance used for collaboration between the stakeholders

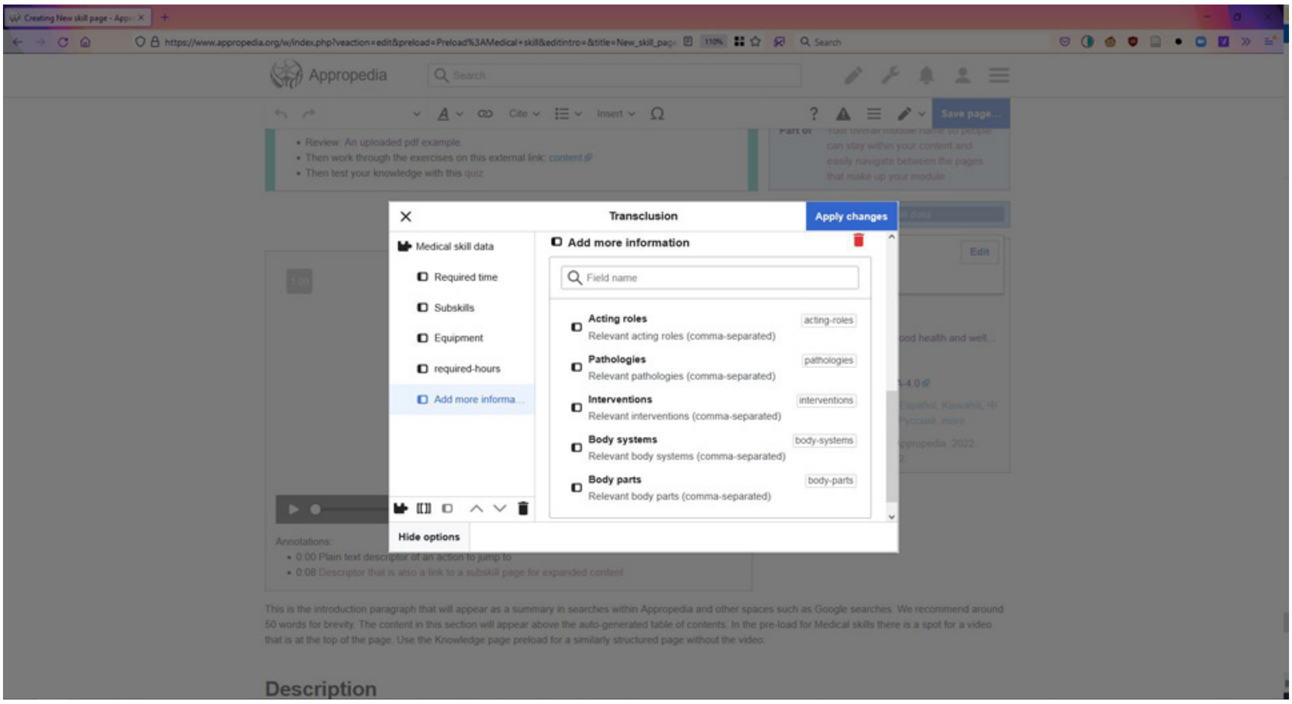
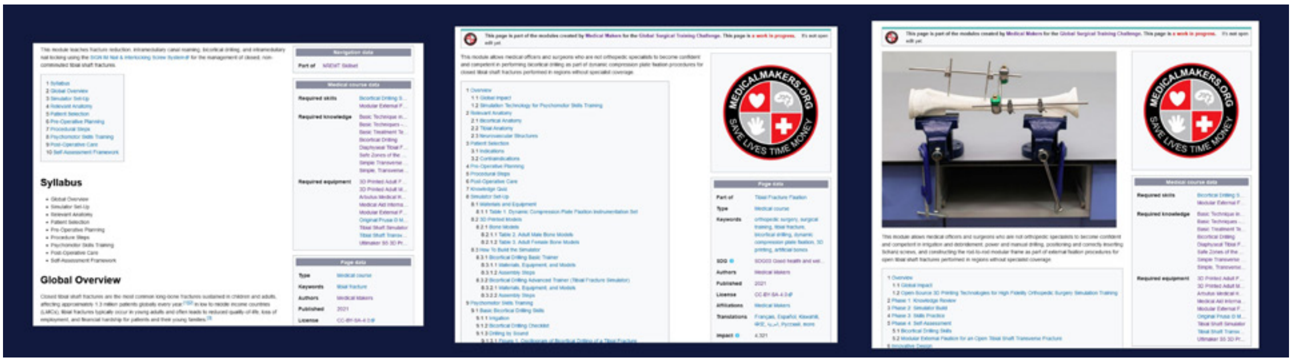


Figure 8: example of documentation progress for one of the most visited medical skills



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