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MEETING REPORT

The Value of Stakeholder Mapping to Enhance Co-Creation in Citizen Science Initiatives

Artemis Skarlatidou[*], Monika Suskevics[†], Claudia Göbel[‡], Baiba Prūse[§,‖], Loreta Tauginienė[¶], Andre Mascarenhas[**], Marzia Mazzonetto[††], Alice Sheppard[*], Judy Barrett[*], Muki Haklay[*], Avinoam Baruch[‡‡], Elina-Aikaterini Moraitopoulou[§§], Kat Austen[*], Imane Baïz[§§], Aleksandra Berditchevskaia[‖‖], Eszter Berényi[¶¶], Simon Hoyte[*], Lotte Kleijssen[***], Gitte Kragh[†††], Martine Legris[‡‡‡], Alicia Mansilla-Sanchez[‡‡], Christian Nold[*], Michalis Vitos[*] and Paweł Wyszomirski[§§§]

This report aims to enhance our understanding of stakeholder mapping for co-created citizen science initiatives. It presents and discusses findings from an international two-day stakeholder mapping workshop with researchers, event organizers, communication experts, and artists realizing citizen science activities. Participants identified examples of co-creation in their work and mapped stakeholders for three co-creation initiatives from the "Doing It Together Science" project. For each case, we provide an overview of the stakeholder groups involved and the lessons derived from identifying actual and potential stakeholders in different phases of each activity and using different ways for mapping them. We demonstrate that not only stakeholder mapping can be diverse, but it may take different angles depending on the characteristics and project timescales, nevertheless adding significant value to any project. We argue that a better understanding of stakeholder involvement may contribute to more effective stakeholder communication, more successful implementation, and a greater impact for citizen science initiatives.

Keywords: citizen science; co-creation; stakeholder mapping

Introduction

Citizen science (CS) encompasses, at its core, a partnership between professional scientists and amateur volunteers in scientific research (Miller-Rushing et al. 2012), although a wider range of stakeholders is frequently involved (Tiago 2016). As CS grows in popularity – but also in diversity of terminology and approaches (Shirk et al. 2012; Hecker et al. 2018) – it becomes critical to understand its inherent complexities. A key to understanding these complexities and improving the way it is practiced requires identification of relevant stakeholders involved in various CS initiatives, the possibilities for their involvement, and their interactions. These issues have been discussed from the perspective of volunteer engagement and retention (Kobori et al. 2016), but have received less attention in terms of exploring and subsequently reducing barriers to participation, while opening the engagement process to multiple stakeholders.

The aim of this meeting report is to enhance understanding of stakeholder mapping as a method that can be used to identify the individuals, groups, or organisations affected by a project or who affect its outcomes. Our emphasis is on co-created citizen science initiatives, which require good engagement with those involved, so identifying stakeholders and their interests is important. We provide insights from an international two-day workshop where we used three CS initiatives from the "Doing It Together science" (DITOs) project to carry out an in-depth stakeholder mapping investigation. Although stakeholder mapping may take different shapes and forms, we provide

[*] University College London, GB
[†] Estonian University of Life Sciences Tartu, EE
[‡] European Citizen Science Association (ECSA) Berlin, DE
[§] Institute for Environmental Solutions, LV
[‖] University of Latvia, LV
[¶] Office of the Ombudsperson for Academic Ethics and Procedures of the Republic of Lithuania, LT
[**] Museum für Naturkunde, DE
[††] Stickydot, BE
[‡‡] Loughborough University, GB
[§§] Université Paris Descartes, FR
[‖‖] Tekiu Ltd, GB
[¶¶] ELTE University, HU
[***] Waag Society, NL
[†††] Earthwatch, GB
[‡‡‡] Lille University, CERAPS, FR
[§§§] Centrum Szkoleń i Rozwoju Ososbistego MERITUM Katowice, PL
Corresponding author: Artemis Skarlatidou (a.skarlatidou@ucl.ac.uk)

here a tangible example of three different ways of carrying out this activity. We build on our prior experience in using stakeholder mapping and we reflect on the observed methodological issues.

DITOs is a European H2020-funded Coordination and Support Action that ran over three years between 2017 and 2019. It was coordinated by University College London (i.e., Extreme Citizen Science group) and involved 11 partners. In DITOs, more than 500 events and a travelling exhibition were carried out and more than 1.3 million citizens across Europe participated in CS and Do It Yourself (DIY) science in the themes of environmental sustainability and biodesign. Owing to the variety in contexts and types of CS initiatives in DITOs, the workshop that we describe here was carried out to understand stakeholder involvement in DITOs--through the random selection of three cases--and to explore effective ways of stakeholder mapping which would subsequently have the potential to improve the way that CS is currently practiced.

The two-day workshop included 27 participants from nine European countries and took place at University College London on 20 and 21 March 2017. The participants were invited based on their background and expertise in CS and prior experience in stakeholder mapping and co-creation approaches. Most of the participants are working in academic and scientific institutions and are members of the Working Group 4 of the COST Action CA 15212 (COST Action on "Citizen Science to promote creativity, scientific literacy and innovation throughout Europe'": https://www.cs-eu.net), although participants from Non-Governmental Organisations (NGOs) and Small and Medium Enterprises (SMEs) were also present.

Co-creation and its relevance to CS

Citizen science varies in the degree to which people participate, with Shirk et al. (2012) saying that "co-created projects are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all aspects of the research process" (p. 4). Participation at these higher levels of engagement incorporates characteristics of co-creation and social innovation (Gebauer et al. 2010). Indeed, it is argued that " ... the defining characteristic of citizen science is its location at the point where public participation and knowledge production [...] meet" (Irwin 2015: p. 3).

The concept of co-creation has its origins in management literature as a paradigm shift encapsulating a new relationship between consumers and producers collaborating in a joint process of value creation (Kambil et al. 1999). Service science theory discusses co-creation as the driving force of customer collaboration to realise market offerings and generate new services (Galvagno and Dalli 2014), while co-creation also has roots in literature on participatory democracy and practices. For instance, Sanders and Stappers (2008) explain that co-creation is at the core of participatory design. However, Ind and Coates (2013) call for the need to understand co-creation outside disciplinary boundaries to add to its meaning a more "sustainable and diverse approach" (p. 86). They argue that it is about "the togetherness implicit in creative processes and the needs of the stakeholder" (p. 87) and continue that "co-creation can be a force for participation and democratisation that does create meaning for all, rather than simply an alternative research technique or a way of creating value through co-opting the skills and creativity of individuals" (p. 92). Co-creation here alludes to meaning and knowledge, mostly associated with open access, collective intelligence, open source and innovation, and a set of principles and values such as trust, social capital, word of mouth, and sense-making (Zwass 2010).

In CS, the meaning of co-creation is relatively loose in comparison with other disciplines. The terms "co-created," "co-designed," and "co-constructed" for CS projects are frequently interchanged. The value-adding potential of co-creation in citizen science has received considerable attention (Regalado 2015; Ferran-Ferrer 2015). It can add relevance, increase impacts, contribute to knowledge production and social innovation, and help participants improve their own skills and courage (Zwass 2010), and community science, which mostly relies on "co-created" projects, has the greatest impacts on education, public engagement, and social well-being (Bonney et al. 2015). Nevertheless, little emphasis has been paid so far to the importance of identifying the stakeholders involved in these initiatives and ensuring that their needs are identified and satisfied through project design. In this report we describe stakeholder mapping exercises to addressing these issues, and we discuss how others can follow a similar approach.

Who participates in CS? The role of stakeholder mapping

Stakeholder mapping has traditionally been used in the fields of management (Freeman 1984; Preston 1990), policy theory (Brugha and Varvasovszky 2000), corporate social responsibility (Duckworth and Moore 2010), human resources (Greening and Turban 2000), and education (Stout and West 2004). It has more recently received attention in other disciplines, such as natural resource management (Geneletti 2010; Reed 2008). Göbel et al. (2017) propose the terminology of stakeholders as analytical lenses to gain a better understanding of parties involved in CS projects beyond professional and "non-professional" researchers. Although stakeholder identification influences the success of CS initiatives as acknowledged in CS literature (Tiago 2016), there are a limited number of stakeholder mapping studies. Those that exist range from *descriptive* (i.e., a description of how stakeholders behave and their actions); *normative* (i.e., focus on "the legitimacy of stakeholder involvement and empowerment in decision making processes"), or *instrumental* (i.e., focus on how CS projects "can identify, explain, and manage the behaviour of stakeholders to achieve desired outcomes"; Reed et al. 2009, p. 1935–1936).

Several benefits of stakeholder mapping in the wider context of CS already have been identified. First, early identification of potential stakeholders can allow for their time involvement. This is particularly important, as there is evidence that including all relevant stakeholders is important for CS initiatives to have a stronger impact (Wiggins and Crowston 2011). Second, sharing data and information in CS requires an in-depth understanding of stakeholders (Göbel et al. 2017; Mazumdar et al. 2017;

Newman et al. 2012). Third, Roy et al. (2012) highlight the importance of effective communication mechanisms at all stages of a citizen science programme, which can be better designed with a good understanding of who is (or should be) involved and therefore how communication can be supported well. Fourth, stakeholder mapping can provide the first step to engage new audiences (Pandya et al. 2012), including the "harder to reach" stakeholders, such as participants with no prior scientific interaction experience, or scientists without experience of engagement as suggested by Bonney et al. (2015). Finally, projects can benefit hugely from harnessing the complex and comprehensive local (or in other contexts, indigenous) knowledge that these groups possess.

In a stakeholder mapping framework informed by qualitative social science methodology, Göbel et al. (2017) identify six stakeholder groups involved in CS projects across different levels of engagement: (1) civil society organisations, informal groups, and community members; (2) academic and research organisations; (3) government agencies and departments; (4) individual volunteers; (5) formal learning institutions for primary and secondary education; and (6) businesses or industry. Stakeholders from these groups make many contributions to CS initiatives, e.g., time, funding, expertise, and equipment. Their degree of engagement varies: Currently Group 1 is more frequently involved in project design and implementation while Group 6 is least involved and only in a few projects. Another analytical use of stakeholder mapping in the context of CS is to study stakeholders' perceptions of the field. For example, Geoghegan et al. (2016) describe an in-depth investigation of motivations for stakeholders (scientists, policy makers, and practitioners) to engage with CS, while Mazumdar et al. (2017) examine stakeholders' opinions on the future of crowdsourcing in earth observation projects.

Workshop methodology

The stakeholder mapping exercise was organised following several guiding documents (including Durham et al. 2014) and case studies (in Göbel et al. 2017 and the LandSense project, see **Box 1**). The literature provides examples of participatory workshop methodologies from different contexts; e.g., agriculture (Foster et al. 1995; Norton et al. 1999), health and nutrition (Casapia et al. 2007), marine conservation (Wheeler et al. 2008), and sustainable living (Moug 2011). However, most of these studies emphasise the participatory workshop outcomes, rather than the process of mapping the stakeholders.

The purpose of the first day of our workshop was to discuss what co-creation is, how it manifests in CS and, based on these, select the DITOs project case studies they would like to use for the stakeholder mapping exercises. We used DITOs projects because many of the participants were working on this project (mainly organising and running activities), so they had an in-depth knowledge of stakeholders participating in the various initiatives. Prior to the discussion, the workshop organisers briefly introduced DITOs and stakeholder mapping activities including a review of examples we mention above (i.e., stakeholder mapping in LandSense). Participants selected three DITOs cases, briefly presented in **Boxes 2–4**, below. Each case has its own distinct characteristics, yet co-creation takes place through various forms in all contexts.

Workshop participants determined the rationale of their mapping exercises (i.e., instrumental, normative, or descriptive; Reed et al. 2009) and decided the level of detail, either listing stakeholders or summarising them by interests and influence. Guidance was provided by a

Box 1: A case of stakeholder mapping practiced by the LandSense project

LandSense (https://landsense.eu/) seeks to build an innovative citizen observatory for Land Use and Land Cover (LULC) monitoring, connecting citizens with satellite imagery to transform environmental decision making. Stakeholder mapping has been applied to outline user requirements and co-design engagement strategies (Mascarenhas et al. 2017). For this purpose, stakeholders for each of the project's demonstration cases on urbanisation, agricultural land use, and habitat monitoring in different countries were identified at the outset of the project. This stakeholder mapping approach allowed a first "snapshot" of the varied actors relevant for the LandSense citizen observatory. From the early stages, co-design was brought about by engaging stakeholders in the definition of the issues relevant at each location. Conversely, identifying relevant issues in each specific context supported further identification and mapping of stakeholders. Such an early-stage stakeholder mapping exercise should take into consideration that the "snapshot" obtained is probably incomplete and can change over time. Stakeholder mapping should thus be considered a project-long iterative exercise, which can benefit from involving the stakeholders themselves.

Box 2: Description of the Co-lab Case workshops

Co-lab is a format for co-creation workshops in that the activities that they involve are based on an interdisciplinary overlap of synthetic biology, design, and art, and they require participants to co-create new knowledge and novel solutions (e.g., prototypes) to address specific topics, which are usually inspired by significant environmental and social problems. The workshops were initiated in December 2015, and they are organised by the Open Science School, an association hosted by the Center for Research and Interdisciplinarity in Paris. By the time that our stakeholder mapping workshop took place, nine Co-lab workshops had been organised in Paris, London, Cambridge, Norwich, Lausanne, Shenzhen, and Beijing, involving different partners worldwide. Co-lab focuses on different biology topics (e.g., synthetic biology and biomaterials) making use of methods from both biology and design (e.g., design fiction, design thinking). Each event is unique, driven and co-directed by different participants, and their topics vary. For more information about the Co-lab workshops see the workshops Manifesto (http://openscienceschool.org/biocolab/).

Box 3: Description of the Into The Night project

Into the Night (ITN) is a CS project, led by Earthwatch Europe and University College London, with funding from the Natural Environment Research Council (NERC) and DITOs to increase public engagement in the UK on major environmental issues. Specifically, the project seeks to highlight the effects of excessive artificial light and includes investigating the well-being benefits of dark skies for humans, plants, and animals in the UK. ITN has a robust scientific basis in terms of existing research on the use of CS for dark sky research (Kyba et al. 2013), and aimed to carry out an effort of co-creating locally relevant efforts of recording and addressing light pollution. It involved various co-creation activities (e.g., setting up bottom-up CS activities to collect light and noise pollution data as well as workshops where participants collaboratively build DIY tools such as artificial glow worms to enable collection and analysis of CS data). ITN had completed its three-month pilot phase at the time of our workshop.

Box 4: Description of the Science Bus travelling exhibition

The Science Bus is a travelling exhibition, organised by Waag Society, which launched in July 2017. The bus travelled for three months through Germany, Slovenia, the Netherlands, UK, Croatia, Italy, France, Greece, Belgium, Spain, and Switzerland, and delivered several hands-on co-creation DIY activities. During our workshop, the bus was still in its planning phase; its planned topics ranged from health, food, and the environment, with activities described as aiming to pique curiosity and explore science (e.g., collaboratively with participants to create yogurt, pH-meters, DIY phone chargers, soaps, sunscreens, particulate matter meters, or bacteria detectors) as well as to collect and share local wisdom and practices from various places in co-creating a knowledge "diary" base to travel across Europe.

manual with sample questions for stakeholder mapping based on Göbel (2019), supplemented with instructions from Durham et al. (2014). These include the following three rounds with example questions listed below:

- **First Round Questions**
  - Who is involved in making the CS activity happen, i.e., initiating the project, organizing day-to-day activities, etc.?
  - What do they contribute to the activity?
  - How frequently are they involved with the activity?
  - Who is not, but should be involved? Why?
  - Is the activity (potentially) relevant to any individuals or groups from the following sectors (e.g., local communities; non-governmental organisations, policy makers)? If so, to whom and why?
- **Second Round Questions**
  - What interest does the stakeholder have in the project?
  - What influence can the stakeholder have on the project?
  - Which parties are likely to be the most influential?
  - How may the stakeholder be impacted or affected by the project?
  - How beneficial would engagement of the stakeholder be to the project and why?
- **Third Round Questions:**
  - Which stakeholders is it essential to involve?
  - Who is preferable to involve?
  - Who needs to be consulted?
  - Who needs to be informed?
  - At which stage of the CS activity does the stakeholder need to be involved/consulted/informed?

All three groups started with a detailed introduction of their case study, brainstorming of possible stakeholders, and grouping them by level of influence in a process and outcomes. In successive rounds of mapping and discussing stakeholders, each group then adapted the questions to their specific case. For instance, the Science Bus team opted for generating different target groups that should be involved in the co-creation activities, while the ITN team opted to focus on who should be involved at different moments along the duration of the project.

The collected data were analysed using the inductive approach of qualitative content analysis (Hsieh and Shannon 2005; Kondracki et al. 2002). We argue that the knowledge on mapping stakeholders, particularly in CS, is sparse, therefore, our inductive data come from single particular cases, allowing us to analyse them as a general statement (Elo and Kyngäs 2008), as presented below.

Results

Co-lab workshops

During the stakeholder mapping exercise three main phases of a Co-lab workshop were identified: "blooming and ideation;" "planning;" and "execution." Specific steps for follow-up, e.g., evaluation, were not explicitly discussed as a distinct phase of the Co-lab workshops.

In each phase, participants identified and reported the involvement of different stakeholders, shown in **Table 1**. Participants focused on identifying and reporting groups of stakeholders, rather than individuals or specific organisations, who should be present in each phase. Special emphasis was paid into the process of setting up and delivering a Co-lab workshop, the involvement of the various stakeholder groups in each phase, the activities that they are responsible for carrying out, and the skills required to justify participation. Participation is mainly through invitation to ensure interdisciplinarity in carrying out co-created tasks.

An important topic of discussion in this group concerned funding as a prerequisite of workshop execution. Stakeholder communication (mainly for sharing Co-lab findings) was highlighted as an essential component. Currently this is mostly ignored, but it is necessary to

Table 1: Co-lab workshop phases and stakeholders involved.

	Blooming & Ideation	Planning	Execution
Activities	Agenda setting	Workshop organisation	Workshop execution
	Securing workshop funding		Communicating results to (potential) funders
Role of stakeholders involved	Agenda setters and funders	Facilitators	Participants
Most prevalent groups of stakeholders involved in previous Co-lab workshops	Civil society (NGOs, trade unions, think tanks)	Civil society (associations)	Science (biologists)
	Science (scientists, public/private research institutions, other experts)	Science (scientists, research groups, students, admin staff)	Designers
	Business (entrepreneurs)	Artists	Others with relevant skills
		Designers	

increase visibility and lead into future funding. During the stakeholder mapping exercise, it was therefore realised that the execution stage should be extended to engage stakeholders responsible for communication and dissemination of the Co-lab outputs and outcomes. The exercise further revealed that previous Co-lab workshops had ignored key stakeholder groups, e.g., policy makers, regulators, industries, and most importantly, community members. These groups, it was argued, may have an inherent stake in the workshop topic, and a greater effort should have been made to engage them to improve co-creation and the impact of the activity.

Into the Night

Into the Night (ITN) has so far engaged CS practitioners, professional scientists leading a UK survey on glow worm distribution, and public and private sector organisations. They were engaged in an iterative process to ensure their needs and goals were accounted for during the development of a larger scale project, which will address light pollution and its impacts. The stakeholder mapping exercise systematically identified, grouped, and prioritised potential stakeholders, who should be included in future workshops and activities. It created a basis for understanding the implications of the communication process for stakeholder engagement, as was also the case with the other two groups. Participants grouped stakeholders into existing contributors, potential contributors, and stakeholders affected by the project. They also considered stakeholders' interest and degree of influence in the project. Compared with the two other groups they looked beyond the scope of the project and considered other contexts (e.g., environmental CS; lighting conditions; off-peak energy consumption). There was extensive discussion around what "influence" means in the ITN context (e.g., influence by running a project, through funding) and how significant these influences are. As shown in **Figure 1**, most of stakeholders who were identified were perceived as having either high (H), medium (M), or low (L) interest and influence in the project. This exercise showed that predicting interest and influence in a project that is still at its early stages is not as simple as initially anticipated by this group's participants. Nevertheless, it led to the conclusion that ITN needs to invest resources to generate stakeholder interest early in the project rather than at subsequent stages when it is perhaps too late to effectively reach and engage with specific audiences, especially those with a high interest or influence in the project.

Science Bus

The mapping for this case study focused on identifying relevant stakeholders from the bus's planned itinerary through Europe. Participants mapped stakeholders within specific themes that they initially identified as potential ways of engaging stakeholders (i.e., "Science Bus as a Tool for working with local communities" and/or "Science Bus as a tool for transferring local knowledge") (**Figure 2**). Participants in this group identified three levels of stakeholder importance. Level 1 includes all stakeholders who are essential to the project (i.e., the project would not exist without their involvement); levels 2 and 3 categorise all other stakeholders in decreasing importance.

This group identified six main groups of stakeholder (**Figure 2**): (1) local community institutions; (2) local grassroots and frugal innovation groups; (3) facilitators (including bus drivers); (4) local governments; (5) exhibition designers; and (6) DITOs partners, who provide connections to other groups, locations, and help among other contributions. Subsequent mapping considered potential needs, motivations, and expectations of those stakeholder groups. Together with other local issues identified, participants acknowledged concerns about the engagement process and the effects that this might have in local populations (e.g., tension caused due to inviting competing organisations to participate). As with the previous two groups, participants extensively mentioned funders as a specific stakeholder group; they expressed concerns about the continuation of a co-creation initiative when funding is limited and the appropriateness of funders in shaping the structure. Participants suggested that although existing co-creation activities are usually initiated (and frequently planned and organised) by project organisers (with or without funder participation), creating stakeholder networks and channels for the effective communication of information at all levels and stages is particularly important. However, the size of the activity (and therefore the size of these networks) influence these processes. A particular difficulty in mapping

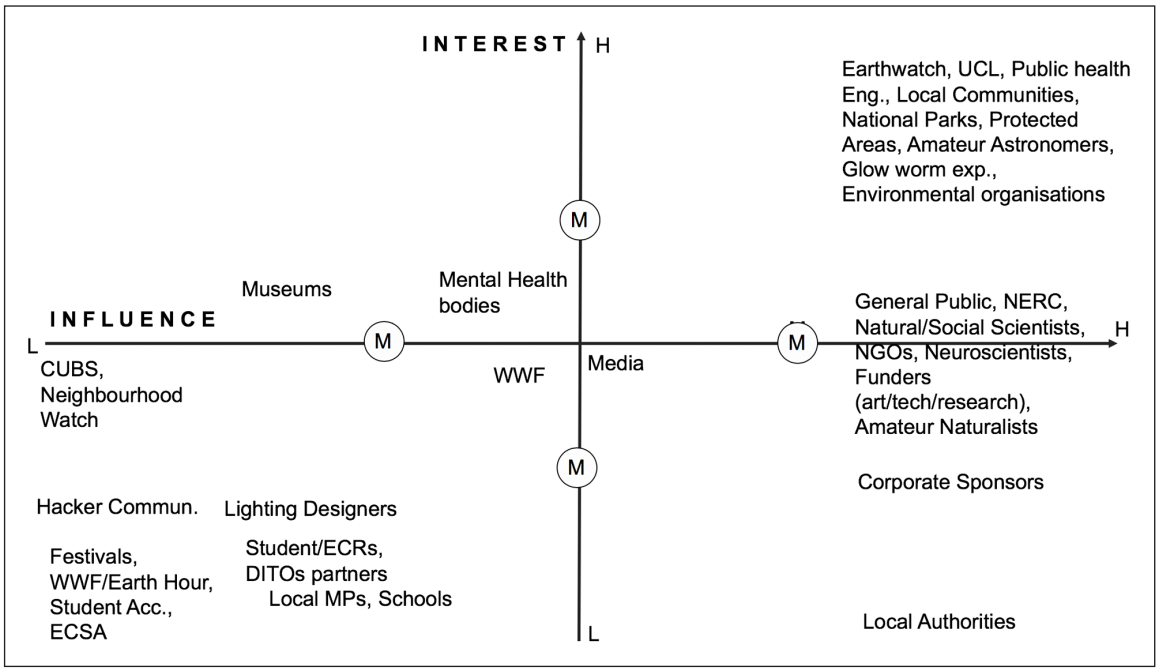

Figure 1: ITN stakeholder mapping result showing stakeholders grouped by their levels of interest (y axis) and influence (x axis). Participants identified three levels of interest and influence: high (H), medium (M), or low (L). On the right-hand side of the graph, stakeholders include those who already exist and contribute to the ITN project (existing contributors); on the left side they inlclude those who should be involved in the project (potential contributors). For example, "Mental Health Bodies" as potential contributors may have a high influence and interest in the ITN project. "Local authorities" are existing contributors and have a low interest but high influence in the project.

	Science Bus, as a tool for working with local communities	**← Both →**	**Science Bus, as a tool for transferring local knowledge**
Level 1	Neighbours, local churches, residents organisations, employers, out-of-class places, community houses	DITOs partners	Facilitator, workshop hosts, trainers
	Local authorities, mayors	Workshop facilitators, bus driver	Activity Designer
	ECSA, local innovators, local citizen science groups, local institutions	Local grassroot communities	Property Owner
			Carers
Level 2	Schools, school holiday organisers	Local press, journalists, local newsletter producers	Sense Box Minister (CS project no DITOs partners)
	Internet based DIY science community, bloggers	Who goes camping?	Retirement home
		Funders (H2020, private, Public)	My dad (retired scientist)
		Bus Sponsors	
Level 3	Insurances		
	Local gathering spaces (bars, sport centers, youth centers)		
	Libraries, neighbours, local suppliers, market stall owners, shop owners, police, gangs, ….	X	X

Figure 2: The Science Bus stakeholder mapping. Three categories of stakeholders include those who are simply engaged in the project (i.e., "Science Bus as a Tool for working with local communities" column), those who develop skills and through their participation contribute to expanding the knowledge of participants ("Science Bus as a tool for transferring local knowledge" column), and those who do both (middle column). Levels 1, 2, and 3 correspond to levels of importance; level 1 stakeholders are essential for the project, level 2 are important, and level 3 are the least important. For example, local grassroot communities can be involved in ways that support the Science Bus activities in order to engage with local communities by advertising its activities to their members. They also may be involved to organise or participate in the organisation of Science Bus activities to better communicate and capture local issues. They are considered to be essential for the successful implementation of the Science Bus activities.

this group was not only that the project was at a very preliminary planning stage, but it further needed to consider relevant stakeholders across various EU countries, and this occasionally included contexts that participants were not familiar with.

Discussion

Retrospective and prospective reflections as variants of using stakeholder mapping

Stakeholder mapping is often used with instrumental goals, i.e., as a tool to aid decision-making (Geneletti 2010; Heidrich and Tollin 2009), and where the mapping exercise can be used to inform future decisions (prospective mapping), as was the case with the Science Bus and the ITN mapping exercises. Here stakeholder mapping can significantly speed up the project design process and subsequently its overall effectiveness. Stakeholder mapping can also be retrospective, e.g., understanding past participatory decision-making processes (see for an example Buanes et al. 2005; Sovacool 2010), so stakeholder mapping is a reflection tool to analyse and learn from past experiences. In our workshop, this retrospective approach for Co-lab and ITN provided beneficial reflective analysis. Indeed, this workshop is another potential application for the methodology, because sharing experience and good practice is important for CS communities. Our main observations about the mapping exercises are shown in **Table 2**.

What types of stakeholder groups are involved and missing in the selected case studies?

As CS practices vary significantly across the fields, our focus on co-creation and a selection of case studies from the DITOs project provided a common ground for the workshop and its analysis, although the three case studies incorporated different characteristics (**Table 2**), which influenced the stakeholder mapping exercise. The Co-lab workshop was analysed retrospectively (in terms of drawing knowledge from past experiences and from already completed workshops). It is a structured event format and of short duration, thus the content and extent of participation in each workshop depends on the topic, so stakeholders will vary. The two main groups involved in all three stages of organising Co-lab workshops are scientists and members of the civil society, although they also involve artists and designers, whose participation connects civil society and science in innovative ways. The Science Bus, which was in the planning stage when the stakeholder mapping workshop was conducted, is a much larger-scale and complex activity comprising a series of pre-defined, fixed-content workshop events at various EU countries. Here, the extent of participation depends highly on the local host. Stakeholder groups include local people, civil society organisations and local authorities, project organisers, and DITOs partners. The bus drivers (who also facilitate and run the Science Bus workshops) are involved as mediating actors (and stakeholders themselves). Finally, ITN combines characteristics of the other two case studies meaning that a pilot study had been completed when the mapping was conducted, while a new planning phase for the next five years of the project had just started. This meant that there was a good understanding of the project's current stakeholders, enabling consideration of potential new stakeholders. The participants included a more diverse range of stakeholders than in the previous cases, including specific organisations with an interest in the project and more generally defined stakeholder groups such as private institutions and think tanks.

Overall, stakeholder groups of CS activities as identified in Göbel et al. (2017) were also found in our three cases. Such groups, e.g., civil society organisations, government agencies, individual volunteers/participants, and businesses, were present in all three cases. Academic and research organisations and formal learning institutions for primary and secondary education were relevant in only two cases. Our workshop identified certain stakeholder groups that tended to be neglected in our three cases studies. For instance, funders are of the utmost importance, but they are often missing as a stakeholder group in the studied CS initiatives. Funders need to be identified early, approached regularly, and project results

Table 2: Overview of purposes, characteristics of the mapping process, and major insights for three case studies.

Cases	Co-lab workshop	ITN project	Science Bus
Purpose of stakeholder mapping	Improving activity through reflection & good practice; support replication.	Reflection on pilot phase and anticipatory perspective for project planning.	Project planning to increasing impact during activity's design stage.
Characteristics of mapping	Retrospective mapping. Initially, stakeholders were actual individuals, who were then grouped in categories (i.e., Civil Society, Researchers, Facilitators, and Participants).	Mix of retro- and prospective mapping. Knowledge of past enables detailed mapping for desired future activity.	Prospective mapping. A much more generic categorization of stakeholders (e.g., local grassroots communities) than the previous two cases
Major insights	Identification of extra participants to be included in workshops (e.g., policy makers) and methodological perspectives, e.g., improve stakeholder communication of results.	Influence and interest of stakeholders should inform prioritisation of resources for their engagement. Who should be involved when in the project?	Reflection on desired impacts (engagement & knowledge creation) for the attainment and exploration of engagement strategies based on stakeholder expectations.

disseminated to them to increase future funding. Policymakers were also found to be often neglected and need to be more actively engaged: Their support is crucial to increase the appreciation of the benefits of CS and evidence-based policymaking. An additional stakeholder group identified through the ITN and Science Bus cases is media, underlining the centrality of communication. Furthermore, the Co-lab workshop and Science Bus highlighted the role of mediating stakeholders – i.e., workshop facilitators/bus drivers – acting as interfaces between various stakeholder groups, supporting the effective communication amongst them and facilitating conflict resolution. In all groups the communication with stakeholders was deemed to be a problematic element of existing projects, and this was thought to be significantly improved by using stakeholder mapping early in the project to identify who should communicate with whom and when (Reed 2008; Reed et al. 2009). Additional stakeholder groups (e.g., local supporters and innovators) appear to exist in specific types of co-creation activities. Our case studies outline similarities and differences in identified stakeholder groups, thus highlighting the importance of stakeholder mapping in co-creation CS initiatives.

Based on our experience, we suggest that criteria for stakeholder mapping should be based upon the aims of the specific stakeholder mapping activity. The common approach to use certain stakeholder attributes (e.g., their power, interests, or knowledge), which then can be plotted on a graph, is not always the most convenient and effective method. For example, when stakeholder mapping is used in a new type of activity, the levels of interest and influence might be more difficult to predict. Additional criteria might also be beneficial for CS stakeholder mapping, such as identifying stakeholder roles, as exemplified by earlier research (Heidrich et al. 2009). In CS, a deep stakeholder analysis that considers the sources of power, such as expertise, formal authority, or money (e.g. Bryson, et al. 2011), or takes the wider context into account, such as biophysical conditions, institutional context, and community attributes e.g., Aaltonen and Kujala 2016) might also be useful.

We found that it was important to ensure ample discussion time in a participatory stakeholder mapping workshop and to clarify the aims of the mapping exercise, i.e., establishing the concrete question, issue, or activity relating to which peoples' and organisations' stakes are examined (Reed et al. 2009). When participants themselves define the aims, there are better conditions for productive discussions. Finally, while stakeholder mapping proved to be a flexible and relatively easy to apply methodology, the power of the approach lies in reflecting on the activity's contextual conditions for a mapping exercise to become productive, e.g., asking what the boundary of the activity is and what constitutes a legitimate stake.

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Competing Interests

The authors have no competing interests to declare.

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