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Co-created citizen science: challenging cultures and practice in scientific research

Jade L. Gunnell, Yaela Naomi Golumbic, Tess Hayes and Michelle Cooper

Abstract

Co-created citizen science offers practical tools for implementing science communication theories by increasing public participation in scientific research, empowering communities and advancing situated scientific knowledge. However, delivering such an approach presents a number of key challenges around funding, fostering working partnerships between scientists and citizens and ensuring all stakeholders receive sufficient benefits from the process. In this essay we draw from science communication and citizen science literature to describe these challenges and discuss the opportunities that will enable co-created practices to prosper.

Keywords

Citizen science; Community action; Participation and science governance

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Introduction

The relationship between science communication practice and research is often a distant one, with limited exchange of learning and experiences [Miller, 2008; Metcalfe, 2019]. To date, there are no standard set of norms and practices that science communicators have agreed upon and few practical resources which provide tools for implementing and analyzing science communication theories in practice [Davies and Horst, 2016]. This discrepancy is associated with the differentiative cultures of science communication researchers and practitioners and the lack of interaction between groups [Gerber et al., 2020]. Recently, citizen science has been proposed as a useful method for implementing science communication practice, with calls to establish a relationship between models and practices of the two fields [Golumbic, Baram-Tsabari and Fishbain, 2020; Hecker, Luckas et al., 2018]. Citizen science is the active involvement of non-scientists in scientific research, generally categorized into three practices: contributory, collaborative or co-created [Bonney, Ballard et al., 2009]. Both contributory and collaborative projects are described as those that are designed by scientists. In the contributory case, citizens are specifically consigned to data collection (for example Branchini

et al. [2014], Meschini et al. [2021] and Kohl et al. [2021]). While collaborative projects offer further participation, whereby citizens, as well as collecting data, may also help refine project design, analyse data or disseminate findings (for example, Baalbaki et al. [2019]). Co-creation is the most participatory of the three models, defined as projects "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 steps of the scientific process" [Bonney, Ballard et al., 2009, p. 11].

While all three citizen science models align with certain aspects of science communication [Sagy et al., 2019], we focus here on co-created projects which is a powerful way to meaningfully engage people in science and which aligns closely with the dialogue and participatory science communication models as defined by Trench [2008].

Concept of co-created citizen science

The concept of co-created citizen science was first described by Bonney, Ballard et al. [2009], who offered a typology for citizen science, orientated around the degree of public participation in the scientific process. Building on the definition above, Shirk et al. [2012] suggested that due to the collaborative nature of co-created projects, the quality of participation, which includes aspects of trust, credibility, relevance and agency, may be a critical requirement for its success. Collectively, Bonney, Ballard et al. [2009] and Shirk et al. [2012] established the notion of co-created citizen science as inviting citizens, i.e. the public, and scientists to collaborate in joint research endeavors where the citizens' goals, needs and interests are served through the project.

Co-created citizen science projects are widely associated with scenarios where citizens have a specific problem, question or issue they would like to investigate [Bonney, Ballard et al., 2009; Hoover, 2016; Ramirez-Andreotta et al., 2014]. Their goal and motivation for participating is to find an answer or solution to their specific issue and is particularly powerful when facing issues such as contamination or pollution that directly affect citizens' health and wellbeing [e.g. Ramirez-Andreotta et al., 2015]. Examples of co-created citizen science projects include, "Making Sense" a citizen sensing project looking to address issues of noise and air pollution in Amsterdam (Holland), Barcelona (Spain) and Prishtina (Kosovo) [Making Sense, 2016]; "The Alberta Furbearer Project" a wolverine population and conservation risk assessment initiated by The Alberta Trappers Association conducted in partnership with Alberta Conservation Association in Canada [Anderson et al., 2020; The Alberta Trappers Association, 2019]; "Caring for Waterhole Creek" a water quality assessment carried out in Victoria, Australia, in partnership with local residents [EPA Victoria, 2018].

The fact that co-created projects often emerge from community needs means that they have an increased interest in delivering direct benefits for citizen communities, such as resource management, actionable knowledge and community empowerment. For example, Ens, Daniels et al. [2016] demonstrated that utilising indigenous invasive species control techniques, can lead to long term sustainable management of resources, increased resilience, in addition to a range of co-benefits for local indigenous communities. Boivin et al. [2014] highlights the

benefits of acquiring relevant, actionable knowledge demonstrating citizens can influence more effective public health interventions when their experiences are incorporated. Finally, the benefit of community empowerment in the cases of Roa García and Brown [2009], Gray et al. [2017] and Phillips et al. [2010] highlight that empowerment can lead to conservation and improved resourse and land management outcomes at the local level. These examples show that co-created approaches can contribute to interventions and change, on a local, policy and community level. Ultimately, by maintaining citizen participation throughout the whole research process, co-created projects ensure that the research questions, methodologies, data collection, analysis, interpretation and subsequent outcomes are grounded in the reality and context of the community in need. This means the outcomes are more meaningful for them than those conducted through research situated outside of the community context [Corburn, 2007; Sorensen et al., 2019].

Such a practice orientates co-created citizen science as striving for a more democratic production of science, placing greater value on the contribution of lay people and providing opportunities for greater societal impact and collective problem-solving [Skarlatidou et al., 2019]. These ideas are in-line with deliberative models of science communication (dialogue and participatory) as they seek to involve the public with science on a more democratic basis [Trench, 2008]. However, current experience with co-created projects within the field of citizen science is limited, with studies, such as Ramirez-Andreotta et al. [2014] few and far between. Thus, providing little evidence in the scientific or grey literature discussing the design, nature or outcomes of co-created citizen science practice. This restricts the understanding of the co-created approach, and the sharing of 'best' practices. Furthermore, the tendency towards action-orientated outcomes contrasts with the knowledge-orientated outcomes which tend to be the principle and accredited purpose of scientific institutions. From this tendency emerges a possible explanation as to why co-created practices are not more widely adopted by scientific institutions. There is no reason, however, why co-created approaches need not deliver rigorous scientific outputs. Codru et al. [2007] and Hawthorne et al. [2015] are examples of peer-reviewed scientific research generated from a co-created citizen science approach. Furthermore, co-created approaches allow scientists access to communities' understanding and interpretations of scientific data in their local context (i.e. local knowledge; lay expertise), interpretations which scientists themselves may not arrive at and which enhance the quality of the research [Hoover, 2016; Corburn, 2007]. This practice moves towards bringing professional and lay expertise into closer alignment [Boivin et al., 2014; Cornwell and Campbell, 2012], combining the two knowledge systems to fill gaps in knowledge and research development [Bennett and Smith, 2007; Corburn, 2007; Cornwell and Campbell, 2012; Ens, Scott et al., 2016].

Achieving such processes is however, exceedingly challenging within the existing cultural contexts. While the prospect of such a participatory approach is appealing, and has been theorized at length in the science communication literature, it is difficult to implement within traditional scientific cultures, demanding a new set of rules, methods and governance for its future development and implementation. In this essay we describe the key challenges facing scientific institutions that look to adopt co-created citizen science processes, and suggest a set of individual, institutional and community changes that may allow co-created practices to prosper. This essay is intended as a catalyst for further discussion and debate, as it

Table 1. Challenges to incorporating co-created citizen science practices.

Resourcing	Challenging funding bodies to be more open and creative about what they are willing to invest in
Fostering partnerships	Challenging the notion of scientists as the sole knowledge holders
Ensuring reciprocal benefits	Challenging traditional scientific outputs, outcomes and impacts

highlights particular tensions (such as resourcing, fostering partnerships and ensuring reciprocal benefits) that challenge the cultures and practice of scientific research and hence need to be addressed to appropriate deliberative science communication practices for future research.

Essay approach

The concept for this essay originated from a symposium on co-created citizen science held at the Australian Citizen Science Association conference in Adelaide, in February 2017. The symposium sought to draw together knowledge, experiences and insights in co-created citizen science practice, from citizens, scientists and citizen science practitioners. Symposium participants were self-selecting and came from a range of institutions, including universities, NGOs, research institutions, government and community organisations, all with an interest in, or experience of, co-created approaches to citizen science. The symposium was orientated around a discursive dialogue about how, when and why co-created approaches to citizen science might be useful. Thematic analysis of the symposium discussion identified several common themes that practitioners considered when determining whether a co-created approach could be successfully or beneficially utilised. These themes included time, scientific needs, project beneficiaries, engagement objectives, ethics, organisational relationships, resources, question scope, community dynamics, motivation and the scale of projects.

Here, the ideas initially collected and identified in the symposium, are explored and built upon, unpacking critical issues around co-created citizen science practice. Using a deliberative and iterative writing process, thematic analysis of symposium content, conceptual debates, literature review, and the authors' experiential knowledge, we identified three key challenges facing scientific institutions in adopting co-created citizen science processes in their everyday practice. These include resourcing co-created citizen science, fostering co-created partnerships and ensuring benefits for both communities and science (see Table 1). While additional barriers may exist for the implementation of co-created citizen science, we accentuate three major challenges which, built on the literature and the experiences of citizen science practitioners, were considered the most prevalent and restricting. Using a science communication lens, we discuss how delivering co-created citizen science fundamentally challenges the culture of scientific practice, and explore the opportunities that will enable such an approach to prosper.

Challenge #1: resourcing co-created citizen science

Citizen science is known to be economically beneficial, achieving data collection and processing that surpasses what research teams can achieve on their own and for a fraction of the cost [Birkin and Goulson, 2015; De Coster et al., 2015; Kaartinen, Hardwick and Roslin, 2013], but projects are still expensive to run with Fauver [2016] reporting costs of tens to hundreds of thousands of pounds for three different citizen science projects. An institution's ability or willingness to resource projects will be determined by the perceived ability of the project to deliver on strategic objectives and scientific outputs. While participating in citizen science projects with clear research outcomes, such as peer-reviewed publications, scientific institutions can justify the cost. However, in co-created projects where the outcomes may be more community and action-orientated justifying the cost may be more difficult.

One factor that institutions must take into consideration is the additional time and resource costs of these more participatory approaches. Hoover [2016] reports how, in a collaborative research project on environmental pollution and human health in a Mohawk community in the U.S.A, both researchers and citizens alike found that the process took much longer than other non-collaborative projects that they had worked on. Projects of a co-created nature require much more intensive communication and engagement than their online or contributory counterparts. This, in turn, has additional resource implications such as spaces to meet, materials and equipment to facilitate collaboration, and more regular and responsive communication channels. In scientific institutions, which tend to have limited resources and often rely on external grant funding, researchers may find it difficult to get institutional support for the additional resources required to carry out co-created approaches.

The acquisition of funds to support such work is a further challenge, particularly in the current economic climate of reduced public funding, and in the existing highly competitive landscape of research financing. The existing funding culture requires detailed project plans with clear objectives and defined, measurable outcomes. Such requirements often exclude more open and experimental projects with uncertain outcomes, including co-created approaches that would involve the community in setting the agenda and direction of research. In addition to this, funding bodies accessible to citizen science projects currently only provide support for short to medium-term projects. For example, in Australia, the Inspiring Australia (the Australian national strategy for engagement with the sciences) citizen science grants and ARC Linkage program (which promotes research partnerships between researchers and business, industry, and community organisations) both look to fund cooperative research approaches and provide funding for a maximum of three and five years respectively [Business.gov.au, 2020; GrantConnect, 2018]. While 3–5 years may be sufficient for conducting traditional research and public engagement initiatives, establishing an impactful working relationship with a community could easily take longer, and may require up to ten years to truly tackle complex problems and create long term change and impact [Ens, Daniels et al., 2016]. In contrast, within the Australian industry-led research funding landscape, there is an understanding that action-orientated projects require medium to long-term investment to reach fruition. The Cooperative Research Centre offers grants for projects for up to ten years [Business.gov.au, 2019], demonstrating that given an established need, governments are inclined to fund long-term and experimental programmes.

As citizen science becomes increasingly accepted and adopted, as is the emerging case in Australian state governments, there is great potential for funding programs to support this shift [EPA Victoria, 2017; Victoria, 2018]. In the Australian State of Victoria, the Volunteering Innovation Fund provides an encouraging starting point, providing short term funding (12 months) under the themes of sustaining, expanding, valueing and understanding environmental and citizen science programs including co-creation approaches [Parks Victoria, 2021; State of Victoria, 2020].

However, emerging and more innovative funding programs like the example of the Volunteering Innovation Fund can underscore the notion that scientist's capacity to adopt new approaches can also be limited. The increased project management and public engagement requirements of co-created projects require a suite of skills not typically expected of a research scientist, such as public engagement, training and teaching, conflict management, volunteer management and collaborative decision-making and consultation [van Vliet, Bron and Mulder, 2014]. In fact, Golumbic, Orr et al. [2017] report how some scientists don't feel equipped or even responsible to communicate with the public. However, opportunities for science communication training are available, in addition to emerging opportunities for specific citizen science professional development. For example, In 2018, the ExCitesS group at University College London offered students studying a geography masters programme a course entitled 'Introduction to Citizen Science and Scientific Crowdsourcing'. The course aimed to introduce students to the theory and practice of citizen science and was also offered online as an open access course. But opportunities like these are few and far between in comparison to the number of citizen science projects operating worldwide. Many scientific institutions are, instead, investing in specialist citizen science teams who can bridge the gap between research and public engagement.

Challenge #2: fostering co-created partnerships

As outlined previously, the definition of co-created citizen science specifies that citizens and scientists work together through all stages of the research process thereby aiming to increase the involvement and responsibility that citizens have in the design, decision-making and interpretation of scientific research. Whilst in contributory and collaborative projects scientists maintain a position of power over the process, co-created projects follow the participatory model approach in pursue of partnerships, ideally sharing power over the scientific process and developing mutual relationships between scientists and citizens.

One of the barriers to sustaining mutual partnership around science-based issues is the prevailing perception of scientific knowledge as superior to other forms of knowledge, meaning that there is a lack of value placed on the knowledge, experience and skills of citizens [Golumbic, Orr et al., 2017]. This lack of value for lay knowledge can lead to researchers' reluctance to share power, meaning that their contributions to a project maintain seniority over others [Clark et al., 2016]. Hence, part of the philosophy behind the deliberative science communication models is that scientific knowledge alone is not sufficient to address the complex problems of today and the application of science and technology in addressing those problems [McCallie et al., 2009; Lewenstein and Brossard, 2009]. Likewise, from the co-created citizen science perspective, scientists are not assumed as the only experts, and lay expertise is seen as valid and important to the research

process. This lack of a sense of value and validity can also sit within the citizen communities themselves, where they lack confidence and a sense of legitimacy in being a part of the scientific process [Holmes, 2011]. Furthermore, it is important not to assume that all citizens want to collaborate with scientists in this way, know how to, or even feel empowered to do so. Citizens may find themselves engaging in a process that asks them to take on more responsibility and commitment than they want to, or feel capable of.

Creating an effective and rewarding mutual partnership can prove to be a challenging task, but where both parties are interested, willing, and have an understanding of what is required to achieve success, co-created citizen science can foster co-learning and bring scientific and lay knowledge closer to alignment [Boivin et al., 2014; Cornwell and Campbell, 2012]. These relationships require both parties to be willing and able to listen and learn from each other's knowledge, skills and experiences, have a commitment to the partnership, and an ability to trust each other [Eleta et al., 2019; EPA Victoria, 2018; Ramirez-Andreotta et al., 2015]. To realise this opportunity, scientists need to relinquish some of their power over decision-making and citizens need to be confident and assertive in sharing their knowledge and expertise. Both parties need to value and trust the knowledge and experience of the other and be aware of the limitations of their knowledge. They need to be willing to be flexible and negotiate the projects' approach and objectives and be committed to working towards a common goal.

Challenge #3: ensuring benefits for both communities and science

Interpretations and applications of the co-created approach depend on the philosophy and ambitions of those delivering the project. Where partnerships are formed with all partners considered equal stakeholders, approaches such as co-created citizen science have the potential to transform the way scientific knowledge is created and adopted [Wagenknecht et al., 2021]. By providing opportunities for the public to initiate projects, or significantly impact the direction of projects, co-created citizen science can enhance public interests and influence research plans and execution [Ramirez-Andreotta et al., 2015]. This consequently encourages transparency, two-way dialogue and collective decision-making between citizens and scientists, which can deliver more sustainable and effective impacts [Bonney, Phillips et al., 2016; Golumbic, Fishbain and Baram-Tsabari, 2019] and increases public acceptance and uptake of the results and research recommendations [Corburn, 2007].

One of the most compelling opportunities of co-created citizen science is the empowerment it can potentially deliver to communities. This has significant implications for creating change and taking action on communities' risks and concerns. As indicated, co-created citizen science projects have often evolved around environmental hazards, such as water or air pollution, and are initiated due to authentic, real-life concerns stemming from local residents' experiences [Ramirez-Andreotta et al., 2015]. The main purpose of these projects is to make a practical contribution, reduce exposure to risks and contaminants and impact policy, regulation and enforcement of environmental standards. The participatory nature of these projects and the fact that they are situated firmly in the context of the community means that lay expertise can be incorporated into the knowledge-making process. Wynne [1989] and Wynne [1995] discusses the reception of science communication as an active, transformative process. We argue

that co-created approaches support this process by the translation of research findings into more appropriate, applicable and therefore more impactful outcomes for the community, while also impacting the core scientific debate. Moreover, participation in the process, by the community, equips them with new skills and knowledge production processes that can empower communities and enhance their capaciy to tackle issues in the future [Ashby, 2003].

In addition to the benefits we can expect for communities, a co-created approach is also capable of delivering high quality, rigorous scientific research that can enhance knowledge production processes. The critical value of co-created approaches, for scientific research, is the added depth and ground-truthing it can bring to scientific understandings of specific problems, integrating social and natural dimensions. Co-created citizen science is particularly powerful where science is focused on applied knowledge production, such as environmental hazards, where the ground-truthing prospective can be applied to solve real-world situations [Ashby, 2003]. Similarly, researchers find that the community's understanding of their local context highlights interpretations of the scientific data that scientists themselves may not have come upon themselves and introduces novel ideas into the research [Hoover, 2016; Corburn, 2007]. Researchers engaged in co-created approaches to citizen science have also found to gain significant social learning from their engagement with communities and exposure to different perspectives and realities of life, that enhance their own understanding of the world in which we live [Jordan et al., 2015].

While co-created approaches have the potential to deliver great benefits for both partners, ensuring that this is realised needs careful and critical reflection from both the community and scientists. Firstly, despite the reported benefits of a highly participatory approach, it may not be necessary, suitable or even possible to deliver the objectives of the project. Different methods, or types of partnership may be better suited and may cost less. As Haklay [2018] discusses, co-created citizen science's highly participatory nature does not make it a superior option; all approaches bring with them a set of benefits and weaknesses and should be selected as the circumstances require. Secondly, there can be tension around the utilisation of the scientific process, as delivering on the communities' objectives may not require the same scientific standards and rigour as traditional research processes. Scientific partners might then question their role and motivation for participating in such endeavours. Equally citizen communities may find themselves engaged in a complex and intensive research process that might deliver scientific outputs, but does not necessarily realise their own goals. It is therefore important at the beginning of any collaborative endeavour, for both parties to reflect critically on whether a co-created approach is the appropriate method for delivering the objectives of all involved. Further, partners should negotiate and agree on how a co-created approach will be utilised to meet that end.

Challenging cultures and practice in scientific research

For many years a criticism of science has been that it is not transferable or applied enough. Science has evolved to keep itself separate from society based on epistemological reasoning [Haklay, 2013]. Science's authoritarian position is "based precisely upon the impartiality and neutrality of the expertise" that it offers [Irwin, 1995, p. 26] and the fact that it produces knowledge in isolation from subjective and social perspectives [Irwin, 1995]. Scientists are traditionally seen as

the elite knowledge holders and producers and there is no room or need for citizens' knowledge or experience. While this approach has advanced our knowledge and understanding of the natural world, leading to many scientific breakthroughs and technological developments of global significance, such as the eradication of smallpox and the development of personal computing and mobile communications, it has also produced many problems. History has shown us that when scientists remain distant from the public and do not consider local expertise, the methods of investigation, interpretation of evidence and thus the findings of the research may be compromised. The flawed management of the BSE (Mad Cow's Disease) crisis, radioactive contamination of Cumbrian lamb after the Chernobyl nuclear fallout and the contamination of blood supplies with AIDS are all examples of how science has failed to deliver on the safety and security that it promised society, through its elite methodology for generating knowledge [Irwin, 1995; Jasanoff, 2003; Wynne, 1992].

As outlined, the practice of co-created projects presents some challenges and tensions for the practice of citizen science and the production of scientific research. But with these challenges emerge new opportunities for growth and development, as illustrated above and summarized in Figure 1. While the challenges described may not be unique to co-created citizen science, how they manifest in co-created practice fundamentally challenges the normative practice of scientific research and the landscape in which it operates. Acquiring funding for research is challenging and competitive for all, but for co-created citizen science, this becomes increasingly difficult when the very nature of a co-created approach does not fit within the bounds of funding frameworks, requires longer-term funding and more open-ended objectives to deliver success. And whilst we can all empathise with the difficulties of collaborative partnerships, within co-created citizen science projects the endeavour to open up the whole scientific process to the public challenges the cultural norms and values surrounding the production of scientific knowledge [Haklay, 2013]. Finally, the tensions around ensuring a mutual benefit for both scientific and citizen stakeholders raise the question about who the scientific establishment is supposed to serve.

Co-created citizen science fundamentally challenges the culture of scientific practice, pushing it to evolve and operate in new ways, to utilise the opportunities that our increasingly open and democratic societies offer [Haklay, 2013; Hecker, Bonney et al., 2018]. The fervent criticism of citizen science as illegitimate and fundamentally flawed, has challenged the field over the last couple of decades. Riesch and Potter [2014] demonstrate that for many this practice is wrong. For these people, citizen science undermines the fundamental principles of the scientific process and scientific culture, such as positivist epistemologies and scientists as objective and detached observers of the natural and social phenomena [Golumbic, Orr et al., 2017]. However, many more epistemological positions now abound which co-created citizen science can draw upon such as community based participatory research [Borda, Gray and Downie, 2019]. Where scientific institutions are willing to adopt different mindsets and philosophies by embracing more participatory approaches, significant benefit can, and has be achieved for both science and society. For example, in the case of Latrobe Valley Air Monitoring Co-design, whereby citizens came together with state EPA to co-create a air monitoring network in response air quality health concerns following a devasting mine fire in the region [EPA Victoria, 2017]. In these increasingly emerging

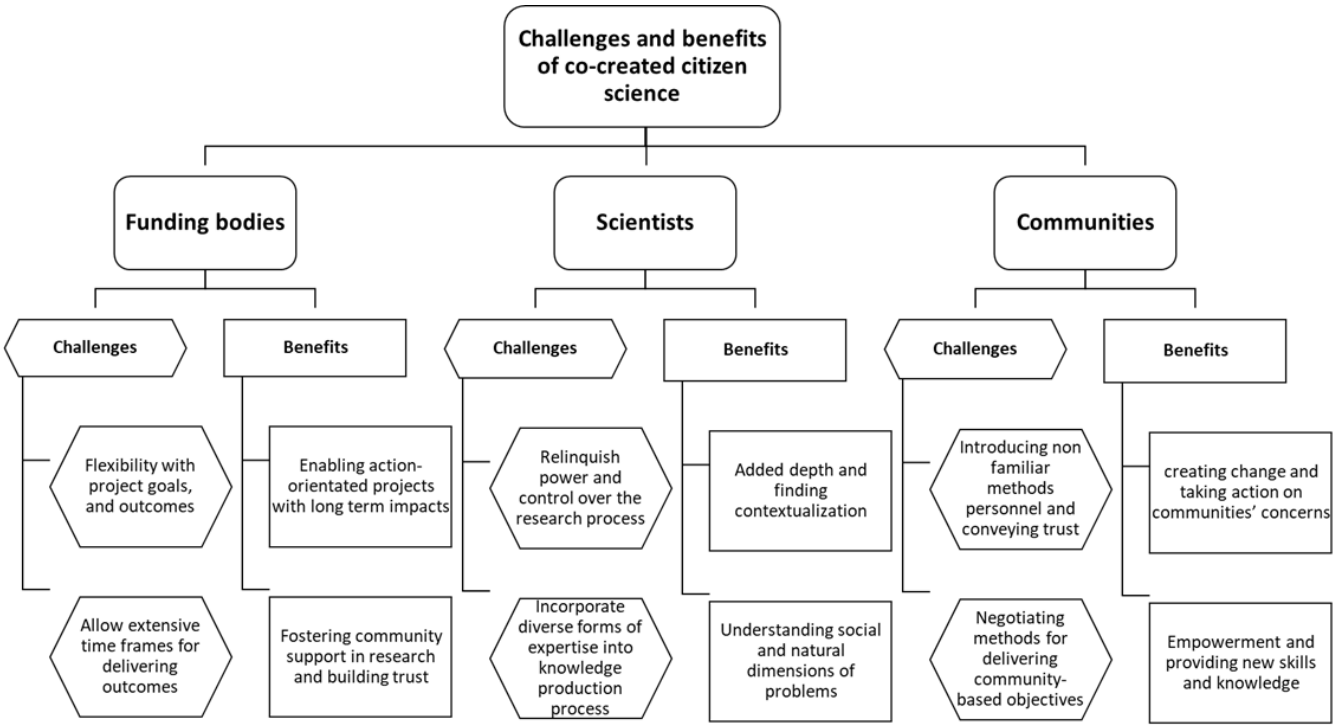

Figure 1. Challenges and benefits of implementing co-created citizen science in traditional scientific research.

example, not only do communities become more empowered and scientific knowledge enhanced, science and society benefit from a more democratic knowledge production system where science is no longer culturally separate from society, but an integrated part, fostering more democratic public decision-making processes, collective action and societal change [Corburn, 2007; Bucchi, 2008; Bucchi and Trench, 2014].

Conclusion

Increasing practice of co-created citizen science approaches reflects a fundamental advancement in the democratisation of science. Co-created citizen science is a valuable practice which is changing, challenging and deepening the relationship between scientists and the public, offering significant opportunities for creating change and taking action, particularly on risks and concerns of communities, such as water contamination, waste and air pollution. As science communication is looking to bridge the gap between theory and practice, co-created citizen science emerges as an effective method to apply, learn from and further progress science communication theories. The nature of the relationships built between citizens and scientists in co-created projects, implements the notion of developing mutual partnerships that are collaborative in nature, share ownership and contribute equally to a project. It is through this mutuality of partnership that projects can deliver benefits for both scientific and citizen parties, practically implementing deliberative approaches to science communication while delivering optimal impact for communities.

As described, one of the barriers to mutual partnership is the prevailing perception that scientific knowledge is superior to other forms of knowledge. This viewpoint

must be dismantled by researchers and practitioners alike, if co-created practices are to fulfil their potential. Finally, the issue of resourcing underpins the ability of co-created endeavours to establish mutuality of partnership and long-term commitment. Financial and human resourcing issues can be addressed by encouraging funding bodies to support more organic and bottom-up research endeavours. Additional challenges may exist in the implementation of co-created citizen science, yet addressing the challenges described in this paper, is the first step in promoting this deliberative approach. Ultimately co-created approaches are developing across society and science communication should use this momentum to push the boundaries of increasingly accessible and democratic science.

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Competing interests

The authors have no competing interests to declare.

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Authors

Dr. Jade L. Gunnell has a background in public engagement, science education, science communication and citizen science. Having worked at the Natural History Museum, London for five years, working in science education and then in the delivery of national citizen science projects, Jade has since completed her PhD studies, at University of Dundee, into the utilisation of co-created citizen science approaches to deliver action outcomes for communities.
E-mail: jlgunnell@dundee.ac.uk.

Dr. Yaela Golumbic is a postdoctoral fellow at the University of Sydney emphasizing on public engagement with science, and ways to make science accessible and relevant to peoples' day-to-day lives and create dialogue between scientists and publics. Yaela has developed, designed and managed several citizen science projects, focusing on co-creation processes and examining its benefits and challenges for science and society. E-mail: yaelago123@gmail.com.

Tess Hayes is an experienced science communicator, who has worked across environmental and climate change policy and communicating science for decision-making. Tess currently works in climate change policy for the Victorian Government. Previously, Tess has coordinated several citizen science projects focusing on identifying and understanding environmental pollution in regional communities. Tess holds a Bachelor of Science (Honours) and is a current Masters student at the University of Melbourne. E-mail: tessannekehayes@gmail.com.

Michelle Cooper has spent the last decade as a science communicator and knowledge translator. As Program Manager for Inspiring Australia, she focused on building partnerships across the industry, community and tertiary sectors, and fostering community led programs through micro grants. Michelle has also worked extensively across Questacon's public programming teams, presenting to a wide range of audiences. She is passionate about finding new ways to connect with groups experiencing marginalisation, and improving public understanding and trust in science. E-mail: michelle@michellecooper.co.

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