International Society of the Learning Sciences

From participants to creators: Considerations for community-led citizen science

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Abstract: There is a plurality of opinions as to what citizen science looks like. We adopt a community-led approach and argue that enabling communities with no or limited science expertise to engage with designing their own scientific investigations is a means to democratising research. To understand the requirements for this form of community participation, we surveyed 150 participants of nQuire - a web-based solution that scaffolds the research design process - and identified factors that enabled and inhibited non-researchers from participating in research. Participants acknowledged the importance of taking part in scientific studies and reported learning benefits in terms of increased awareness and behavioural change. The majority of participants expressed interest in joining studies in the future, yet reported that they are rather unlikely to create their own investigations due to a lack of time, skills and support needed. Implications for the design of community-led citizen science are discussed.

Introduction

Researchers have been engaging the general public or non-researchers, with research activities for years. Many used to refer to, and treat research participants, as passive agents or "subjects" of research. In 1998, an advisory board from the National Health Service (NHS) in England moved away from the term "subjects" and replaced it with "participants", encouraging researchers to abide to a *"firm commitment to involving consumers in research—not as "subjects" of research, but as active participants in the process of deciding what research should take place, commissioning research, interpreting the results, and disseminating the findings"* (Boynton, 1998). Since then, the direct involvement of people with scientific or research activities is found to vary. Under the banner of Citizen Science (CS), we have seen the public collecting or processing data to support research activities led by scientists such as making or transcribing biodiversity observations. In other cases, it is involved in other aspects of the research processes like negotiating and deciding on what to study, how to collect and analyse data, or contribute to reports and publications (Shirk et al., 2012; Haklay, 2013).

Recently a further shift in terminology has been observed. Participation in CS is referred to as Community Citizen Science (CCS). There is a growing emphasis on bringing together communities to examine personally relevant and authentic topics and identify solutions that best match local needs (Audubon Center, 2018; Herodotou et al., 2021). The participation of the public in research has been viewed as a means to promote inquiry learning and critical thinking (Herodotou et al., 2017) and develop agency to solve global societal issues such as sustainability challenges (Sauermann et al., 2020). In this paper, we build on this definition to argue that CCS or community-led CS is a methodology that can *democratise research* by opening up all the stages of the scientific process to communities and individuals and allow the public to understand, get motivated and take part actively in these processes. This is not a straightforward endeavour; it requires capacity building in research institutions and organisations in order to change established perceptions and practices of how participants engage and support research, while at the same time, empower communities through, for example, appropriate training and technological tools, as to how to contribute or pursue their own research agendas in ways that are scientifically and ethically robust and thus acceptable by the research community.

Amongst the challenges reported when initiating or conducting a CCS project are the financial viability of the project, concerns about the quality of data, a lack of integration with learning, time demands to plan for such a project, and little appreciation in academia and policy (Hecker et al., 2018). There is often a lack of time and resources to design a project well, promote it and establish communication channels with participants, while technological skills are often needed for running it. On the other end of the spectrum, there are concerns about the accuracy of data collected and whether sampling is representative and sufficient. Technological development and innovation can be a means to overcome some of these challenges including having volunteers designing their own projects, communicating project findings during and after the project ends and sustaining engagement with participants, using web-based tools. In particular, at The Open University UK, we have developed a web-based platform - the nQuire platform (nquire.org.uk) - for managing the research process from start to end. Our intention is to enable non-researchers to become active creators of research and take control in defining and pursuing their own personally-relevant research agendas, with support from technology and research experts.

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In this study, we surveyed 150 nQuire participants who had taken part in at least one nQuire study in the past. None of them was involved in designing or managing their own study. Our motivation behind this work was twofold: the anecdotal observation that individuals with limited or no scientific background were less likely to show interest in setting up a study on nQuire, and the very low response-rates accompanying completion of online research (e.g., surveys). Therefore, in this study, we aimed to identify the factors that facilitate or inhibit (a) participation in scientific research as led by scientists and (b) intention of participants to create and lead their own research. In particular, we identified motivations of taking part in nQuire studies including any learning benefits, and sought participants' future intentions to participate and create their own studies. In the next section, we describe a learning-oriented theoretical framework this line of work is drawing from.

Theoretical background

Community Citizen science (CCS) shares similarities with Community-Based Participatory Research (Tremblay et al., 2018) in the sense that participants and researchers are perceived as equitable partners who are engaged in all the stages of scientific work with the aim to benefit communities and bring desirable change and development. What is unique in our approach to CCS are: (a) an emphasis on large-scale research, stemming from traditional conceptions of citizen science as a crowdsourcing activity, and (b) an explicit focus on facilitating participants' life-long learning and development. The former points to the engagement of the public with research at large-scale; this can be enabled by web-based technologies and tools that facilitate participation in research. Large scale research has the potential to engage more and diverse voices with research (especially when appropriate sampling processes are adopted), while it can be particularly suitable for pursuing research with communities that are not geographically bounded but defined by common problems or common interests. The latter refers to a learning-oriented approach to understanding and structuring engagement with research, which we coined as Community Inquiry (Herodotou et al., 2021). Community inquiry refers to participation in research through engagement with inquiry learning processes. Drawing from Bloom's taxonomy (Anderson et al., 2001), community inquiry can be structured upon the following learning objectives, through which participants can be guided to design their own investigations: (1) identify or recall an issue of interest or concern, (2) understand this issue through explanations and interpretations that result in defining specific and measurable research questions, (3) apply specific methods to answer these questions, (4) collect and analyse data emerging from these methods, (5) evaluate findings and the degree to which they answer given research questions and (6) create reports, publications, social media content for sharing findings. Scientists and technology are seen as an integral part of the process of design; scientists should scaffold communities to meet the above learning objectives, for example, by sharing expertise about the pros and cons of specific methods of data collection or discussing limitations of a given method of data analysis. Technology could help communities author their studies, collect and access data, and disseminate findings. In the next section, a technological solution designed to scaffold community-led research is described.

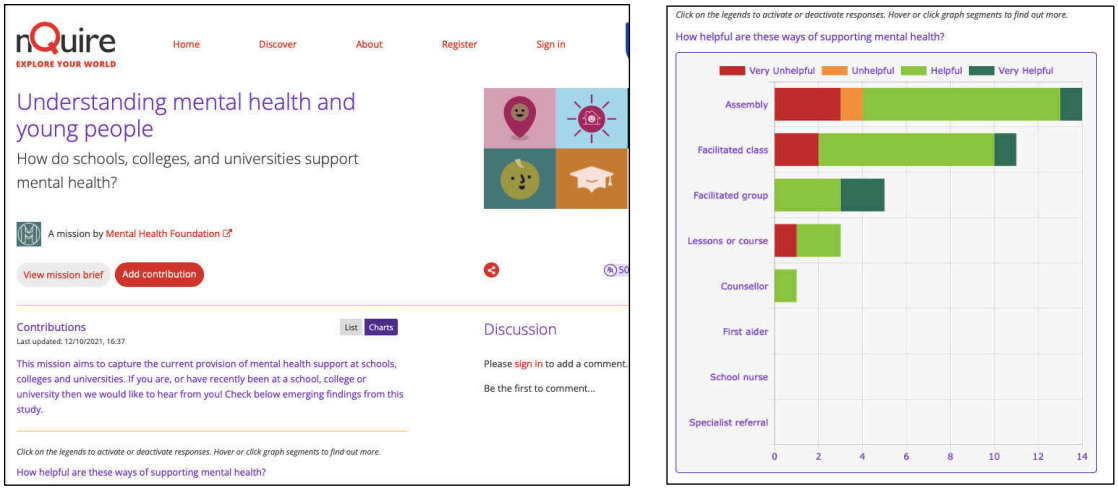
A technological solution for community-led citizen science

The nQuire platform (nquire.org.uk) has been designed with support from the Open University/BBC partnership in an effort to engage the general public with scientific work in ways that support their interests, learning and development. It has been iteratively designed by educational experts and in close consultation with end-users following principles of design-based, participatory research (Herodotou et al., 2018). nQuire enables communities or individuals to, either take part in scientific investigations designed by others, or be guided to design their own, personally relevant studies.

In terms of the former and as a means to support learning processes, participants receive *immediate* feedback: (a) after submitting their responses to an investigation (called a *mission*) in the form of narrative (text) informing them about issues related to the investigation they took part in and suggesting further relevant readings and studies. Also, they can receive *personalised* feedback based on their responses to specific questions, for example, the degree to which they can identify misinformation in news or get recommendations about how creative activities can improve their wellbeing, and (b) when visiting a mission in the form of data visualisations (interactive graphs of collected data) (See Figure 1) and reading, commenting and liking other people's actual responses to the mission questions. We perceive this as a means to open up the process of data analysis to the public and re-engage people with missions more than once, as they can revisit the mission at any time and observe how emerging findings are changing the more people take part in a study. In addition to this and following existing guidelines (Tweddle et al., 2012), the benefits from taking part in a mission are clearly communicated to participants and stated in the mission brief. Similarly, experiential learning or physical practice - shown to be effective in supporting learning processes (Alhajri et al., 2018) - is promoted by asking participants to complete

hands-on activities for data collection such as taking photos of nature, and measuring temperature and growth of trees.

Figure 1 A nQuire mission providing immediate access to data findings



Two mechanisms support participants in designing their own scientific investigations and taking control of the research process: (a) technology and (b) collaboration with scientists. The first mechanism is an authoring tool that guides the process of designing, testing and iterating a study through a series of steps including instructions about how to set up a "Big question", selecting different types of questions that enable the collection of text, image, map location and sensor data, enabling personalised feedback in the form of text or visualizations, piloting functionality (any data collected during piloting are deleted when the mission goes live), and downloading data collected after a mission goes live on nQuire (more details about the functionality of the authoring tool can be found in Herodotou et al., 2021). Participants can choose to create or take part in (i) confidential missions in the sense that all responses are private; anonymised data files can be accessed and downloaded by a mission author only, or (ii) social missions where all responses are open to the public to read, comment and like.

The second mechanism that scaffolds participants when creating their own investigations is a thorough process of review and approval led by Open University scientists that ensures the scientific and ethical quality of proposed studies (Herodotou et al., 2021). OU researchers communicate with mission authors to review, provide constructive feedback and suggest improvements to proposed investigations in ways that are scientifically valid and ethically correct. The process of approvals includes reviewing aspects of the mission such as the language and structure of the mission, ethical considerations, originality, copyrights, piloting and ensuring authors share interim and final reports with findings with their participants via nQuire (Herodotou et al., 2021).

The majority of missions on nQuire have been designed by academics or researchers affiliated with universities in the UK. Other missions have been designed by organisations such as the Mental Health Foundation, the Young Foundation, BBC Springwatch and BBC Weather, and the Royal Meteorological Society. One mission has been designed by an individual with research expertise and interest in engaging communities with research. These insights suggest that organisations with research expertise and/or interest in doing research and engaging with the public are those likely to use the nQuire authoring tool and initiate their own studies. The question raised is how we can engage individuals and communities with limited or no research expertise and interest in scientific investigations with the process of designing and implementing a scientific investigation.

Community-led research is timely; communities are better aware of where problems in their communities lie and have a vested interest in finding solutions (Whittle et al., 2012). Societal challenges such as sustainability transitions towards for example renewable energy use could be better addressed if communities were engaged in the problem definition and the framing and generation of potential solutions (Sauermann et al., 2020). Proposed solutions would be owned by communities and thus more likely to be adopted and applied in sustainable manners, as opposed to being imposed by research and policy experts. The online implementation of nQuire and the catering for large-scale research mean that concerns about sampling and reliance on small, atypical samples (Weigelhofer, & Pölz, 2016; Whittle et al., 2012) can be addressed as, with appropriate advertisement strategies, different populations can be reached. Also, nQuire visualisation tools enable awareness of the locations data are collected from that can inform promotion interventions to increase geographical sample representation. We acknowledge

that access to technology and the internet relate to persistent socioeconomic inequalities (Fiske et al., 2019) that may exclude certain populations from accessing the benefits of community-led research and these should be examined further and addressed. In this study, we consulted participants of nQuire missions in an effort to understand the factors that enable or inhibit this cohort of individuals from taking part, creating and pursuing their own scientific investigations.

Methodology

Survey questions were hosted in the JISC online survey platform. We asked participants to state the number and type of nQuire missions they took part in, their motivations for taking part in these missions including any learning benefits (to understand the reasons why people engage with scientific work) and their intention to take part and design their own study in the future. We emailed participants who took part in a scientific investigation or mission during the last year, and who had indicated at that time that they consented to be contacted about future studies. Closed questions were analysed using descriptive statistics (summary graphs and tables), while open-ended questions followed principles of thematic analysis (Kvale, 2007), capturing and reporting diverse voices and perceptions. We received responses from 150 participants. Participants were over 16 years old, as per the age limit for using nQuire. This research project has been reviewed by and received a favourable opinion from the Open University's Human Research Ethics Committee.

Results

The vast majority of respondents took part in one mission only (85%). Ten people (6.67%) indicated they had participated in two missions, six (4%) in three missions, a further six (4%) in 4-5 missions, and one person stated they had been involved in 11 or more missions. The topic of the missions participants took part in varied. As shown in Table 1 below, a majority took part in missions related to the environment including birds, pollinators and gardens. 20% of participants took part in literature-related missions and 12% in climate-related missions. Participation in missions was influenced by a number of factors including the range of mission topics available at a given time on nQuire as well as the degree of promotion of each mission. For example, the Gardenwatch missions were promoted by the BBC during the Springwatch 2019 TV series and reached more than 230K contributions.

Table 1
Number of participants and content of missions

Topic of mission participants took part in	Number and % mentioning (where 100% = 138)
Birds, pollinators (e.g., bees), mammals, worms	50
Therapeutic value of sounds of nature	7
	Total: 57 (41%)
Novels, literature, characters	27 (20%)
Climate related (heatwaves, climate anxiety)	17 (12%)
Covid-19 related	12 (9%)
Cognition/memory/sound	6 (4%)
Astrobiology	1
Chronotypes	1
Online teaching and learning	1
Others (participants could not recall or were unsure about the name of the mission)	14 (10%)

The main motivation for taking part in a scientific study on nQuire was to contribute to research and science (59%). A number of other participants participated because they believed that helping with science is

important (13%) or had an a priori personal interest in the topic of the investigation (11%). 10% wanted to learn more about the topic of the investigation, 5% wanted to experience what is like to participate in a CCS project and 3% stated other reasons.

In terms of learning in particular, a substantial number (43%) said that there was no change in their knowledge and explained that by (a) not remembering a lot about the mission they took part in and this inhibited them from being able to reflect on their learning, (b) previous knowledge about the topic: "*I'd already learned to recognise different species of bumblebee, but the project just wanted "bee" or "butterfly"*, and (c) not being informed about the findings of the study: *"Haven't heard any results"*. The latter stresses the important role of sharing findings with participants during and by the end of a project that can support their learning.

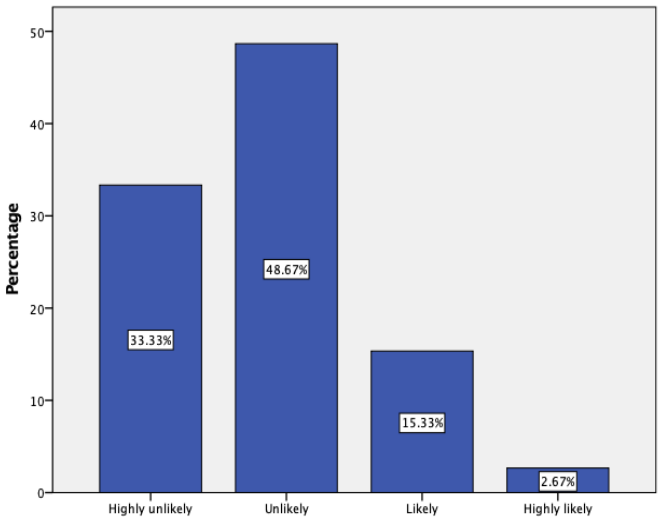
A majority of 48% said they know a little more about the topic of the mission, and 8% a lot more about it. Those participants reporting changes in their knowledge in terms of (a) increased awareness about the topic: *"I have become more aware of the diversity in my garden"* (Participant 1); *" questioning as to how a particular book has influenced/affected me on various levels, e.g., perception challenged, emotional response, escapement from the everyday, stimulated interests/new ideas, etc."* (Participant 2), *"Aware of what plants are likely to benefit insects and keen to make my garden more insect and pollinator friendly*" (Participant 71*).* (b) desire to learn more about the topic: *"The knowledge I gained has given me a desire to find out more through books. I would like to be involved with gaining practical knowledge especially with identification"* (Participant 13). (c) a change in everyday habits: *"To listen to more ambient sounds while out walking and not just plugging my headphones in. This has led to my walks making me feel more productive and calm." (Participant 32), "It was good to actively look at the environment of my garden and observe the insect life closely, I enjoyed the opportunity to slow down and take the time needed to identify then photograph the individual species...this is something I will do again. I actively garden for the benefit of wildlife anyway but this survey helped me understand the benefit of that on a more visceral level" (Participant, 20),* (d) taking action to support biodiversity: *"It led me to read up on helping pollinators and providing habitat in my garden"(Participants, 44), "I set up an Instagram account and posted photos on the [mission name] it encouraged me to take part in other surveys." (Participant, 83).*

A great majority of 89% expressed an intention to take part in future missions, stating that this is likely or highly likely to happen. 11% stated that this is unlikely. Their follow-up explanations showed that, such an action would depend on (a) a personally relevant research topic: *"If something was of interest to me I would participate" (Participant, 102)*, (b) time and effort required to take part: *"If I get invited and have time while the Mission is open then I probably would take part, especially if it's short and can be done at any time." (Participant, 54), "depending how many questions i need to answer" (Participant, 67),* (c) a general motive to help with science: *"If it helps with furthering scientific research"* (Participant, 134), (d) prior expertise in research: *"Volunteer entomologist, survey invertebrates. Volunteer in a research group at London NHM for many years. Record garden birds for BTO. Have MSc in Biological Recording." (Participant, 139),* (e) the possibility for unexpected discoveries: *"Finding something unusual would prompt me to take part unsolicited." (Participant, 87),* (f) having their voices heard: *"It is a way of having my understanding heard by someone relevant, rather than the rubbish from the media" (Participant*,103) (g) general interest in taking part in research: *"always happy to take part in surveys" (Participant, 122), "I love taking part in questionnaires and surveys. I am passionate about literature and reading" (Participant, 79).*

As shown in Fig. 2, only a small percentage of participants expressed an intention to design their own missions in the future and this was explained by (a) having the skills or competence to do so: *'I do this stuff off my own interest already' (Participant. 13), 'I'm a postgraduate social scientist, and I have a lot of interest in doing my own research. Some of it is unlikely to be properly funded through but it would still be interesting to do some surveys and have a go with it.' (Participant, 51),* and (b) having significant prior knowledge about the topic that can help them in designing a mission: *'Having expanded my knowledge on the importance of such a wide variety of pollinators I am wanting to survey a 1.75acre traditional hay meadow to establish how it is used by pollinators and other wildlife so decisions on future management and how it can be improved for wildlife can be made.' (Participant, 77).*

A large percentage of participants (83%) considered it unlikely or highly unlikely they would create their own study. Amongst the reasons given for this were (a) a lack of time: *"Lack of time to design, analyse and make useful use of the data" (Participant, 45),* (b) a lack of knowledge and skills: *"I would not have the knowledge of how to do this" (Participant, 61), "Not qualified" (Participant, 24), "I don't really have a suitable topic for inquiry" (Participant, 73), "I'm not that inventive to establish a project" (Participant, 81),* (c) a lack of support: *"I just don't have the type of work environment that would warrant me embarking on such a project" (Participant, 133)*, and (d) a lack of awareness that this is possible: *"I wasn't aware it was possible" (Participant, 101),* and (e) creating a project is not for the general public: *"why should I?"(Participant, 22), "There is no reason why I should (this is an odd question)" (Participant, 109).*

Figure 2 Likelihood of creating your own study in the future



Discussion

In this study, we surveyed 150 participants who took part in research studies or "missions" hosted on nQuire - a community citizen science (CCS) inquiry platform. The majority of participants participated in one mission, yet they reported an interest in taking part in more missions in the future. Half of them reported learning benefits after taking part in a mission expressed, as in other studies (Herodotou et al., 2020) in knowledge improvement, in particular increased topic awareness and a desire to learn more about the topic under study. Some responses revealed evidence of identity change or agency (Ballard et al., 2017) including changes in everyday habits and taking action to support biodiversity initiatives after taking part in a mission. Participants who did not report any learning benefits were either already knowledgeable about the mission topic or they had not been informed about the project findings, stressing the importance of sharing findings with participants and validating them as genuine contributors in research, as this could promote learning, and the value of accessing collected data and project findings (de Vries et al., 2019). Showing the personal and societal benefits of a study "constitute an effective informational nudge" that was shown to motivate further participation and increased awareness about environmentally-related topics (Cappa et al., 2020). Some nQuire missions related to literature, Covid-19 and pollinators have shared findings with participants, yet others have not done so yet and this may explain why some participants raised the need to access findings. These insights have informed the nQuire process of approvals which now requires authors to upload interim and final reports with findings to the platform as a means of providing feedback to participants and facilitating engagement. Participants receive email alerts when findings are available.

Aligning with existing studies (Jennett et al., 2016), the main motivations for taking part in a mission were to contribute to scientific research, the importance of helping with research, an *a priori* personal interest, and curiosity expressed in a desire to learn more about the topic. Participants' intention to participate in future missions was explained by multiple factors including (a) some of the aforementioned motives such as a desire to help with science and a personally relevant topic, (b) practical reasons including time and effort needed to take part in a mission, favouring short investigations, (c) prior research expertise that could help a mission, (d) the possibility for unexpected discoveries, and (e) to share personal opinions and have their voices heard.

As reported by participants, the transition from participating to creating scientific investigations is not a straightforward one; we observed a great majority of participants reporting that it is unlikely or highly unlikely that they would create their own mission. Amongst the factors explaining these perceptions were a lack of knowledge and skills for designing a study, a lack of support, and a lack of time. Of special interest is the fact that some participants were not aware that it is possible for them to design a study or could not see the value or benefit of having themselves doing so. These findings suggest that the shift from *participants* to *creators* necessitates concerted efforts in order to, first, raise awareness about the role communities and individuals can play in decision making and how their participation can contribute to solving societal problems in ways that best meet their needs. Second, training resources and tools are needed to support skills' development, scaffold the process of design, and lead to designing robust and ethical scientific investigations. Online platforms such as nQuire can support the process of designing personally meaningful projects by making explicit the design process through a series of steps and collaboration with scientists, whereas the provision of immediate feedback to participants after taking

part in a study and data visualisations allow for ongoing feedback that can support learning and motivate further participation.

Conclusions

One of the limitations of this study was the timing of the survey circulation as some participants had difficulties to recall the specific study they took part in and accurately report on its impact. Future studies should time such assessment close to when a study has been completed or embed questions assessing e.g., learning, motivation in the design of a study. Also, a single CCS platform, nQuire with specific design affordances has been studied. CCS platforms with different functionality are likely to promote other forms of community-led research, focusing on specific stages of the scientific work. For example, Zooniverse can scaffold the process of data analysis by enabling access to data collected by scientists, whereas iNaturalist supports the process of data collection and identification by enabling communities to record and upload species of biodiversity. As such, they are likely to support different forms of learning and engagement. In addition, the process of enabling non-researchers to design and implement their own studies necessitates further and more in-depth examinations. This study provided initial insights as to people's perceptions about community-led research and associated barriers. Further studies should engage with specific communities using e.g., interviews, focus groups, observations to understand specific requirements and trial interventions that can empower people to initiate their own studies and start thinking of themselves as scientists.

Careful consideration should be given to the time and effort needed for the general public to take part in CCS activities. In this study, survey participants valued the importance of helping science and expressed interest in taking part or initiating CCS activities, should time requirements be considered. Reflecting on these insights, bite-sized learning might be an appropriate approach to engaging the general public with CCS in ways that are not time consuming. Bite-sized learning (Manning et al., 2021) refers to activities that are short, focused on achieving one learning objective at a time, and less cognitively demanding. Taking as example the nQuire missions, a study could be divided into a series of separate, short missions, with few questions in each one and shared with participants at different points of time. For creating a community-led mission, this may mean that the different stages of scientific work become separated; for example, brainstorming ideas about a mission's big question could form a mission on its own. Similarly, identifying the most appropriate methods of data collection could be a separate voting mission.

In terms of pursuing community-led research, there is a need for researchers to communicate clearly the benefits of such activity for how decisions are made and how the voices of different people can be considered in the production of knowledge. Also, they should showcase ways such activities can be scaffolded through support from technology and scientists. Community-led research should be seen as an interdisciplinary activity where researchers and communities work closely together to share expertise and understanding and design studies that are inclusive and considerate of the specificities of a community.

Finally, the Open University/BBC partnership showcased the significant role large and well-known organisations can play in engaging the general public with CCS. The BBC has partnered with the Open University for over 50 years to provide access to learning at scale, at first via late night TV lectures, and recently through the co-production of content for TV, radio, podcasts, social and digital media. Encouraging the public to join or initiate CCS activities could be actively promoted as part of Open University/BBC social good agenda, bringing the public closer to science and supporting the development of scientific work. The development of CCS capacity in such organisations could be actively pursued through collaboration with institutions with expertise in CCS such as museums, charities and universities.

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Acknowledgments

We would like to thank all 150 participants for their time to complete this survey and inform our efforts of how to engage communities with scientific research.