Institute for Community Studies
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UK Research and Innovation

Valuing and enabling citizen science:

Lessons from the Citizen Science Exploration Grant programme

Institute for Community Studies, August 2022

We believe that involving communities leads to better decision-making.

About the Institute for Community Studies

The Institute for Community Studies is a new kind of research institute with people at its heart. Powered by the not-for-profit organisation, The Young Foundation, the Institute works to influence change, bridging the gap between communities, evidence, and policymaking.

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Report authors: Dr Helena Hollis, Thomas Rolfe, Sian Whyte and Richard Harries

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Executive summary

In 2019, UK Research and Innovation (UKRI) funded 28 Citizen Science Exploration Grant projects. This was part of its ongoing work to explore how researchers can work with diverse groups to participate with, and collaborate in, the research and innovation process - and to test opportunities for building citizen science methodologies into research.

This report sheds light on the practical and conceptual issues around citizen science approaches, contributes to knowledge about citizen science as a research method, and makes a number of recommendations for future research and funding design. Some of the findings and recommendations confirm those already established by others involved in citizen science and public engagement with research. However, this programme also offers some novel insights into citizen science as an expanding methodology for involving people in research, and into how it can best be supported in the future.

Summary of key findings

Overall, our findings suggest that citizen science has the potential to:

- establish and build meaningful relationships between researchers and wider society
- enable co-production of research with citizens in addition to citizens collecting high quality research data
- integrate scientific topics into social, political and wider issues, with advocacy being a key element
- be an important catalyst for co-learning and empowerment for both researchers and citizens
- stimulate ripple effects beyond the project that extend its impact
- generate high-quality data and materials

A. Thematic analysis

Our analysis of CSEG project reports reveals three key insights:

1. Learning and empowerment are key outcomes of involving people in research

Learning from citizen science is valuable for researchers and citizen scientists in the following ways:

For researchers:

- Learning new skills, both practical and methodological, particularly about participatory research
- Learning about specific local contexts

For citizen scientists:

- Learning about specific subject matter, issues and contexts
- Learning new skills, both practical and methodological, including how to be a researcher
- Learning framed as awareness-raising

2. Citizen science enables different levels of public participation

Approaches to participation differed between projects, demonstrating different ways of understanding what citizen science means (and how this can change over the lifetime of a project). We identified three key models:

- **Citizen scientists as a source of data,** where engaging a broad and diverse body of participants to collect samples, classify data, and pilot technology, was seen as an egalitarian approach to research.
- **Citizen scientists as co-producers,** involving participants in decision-making about research design at discrete stages or throughout projects.
- **Shifting understandings of participation,** where some researchers were prompted to revise their original plans and increase co-production with participants for various reasons.

3. Citizen science can achieve sustainability in different ways

We found important nuances relating to achieving sustainability of citizen science approaches:

- **Social, political and issue engagement could be an outcome**, and a broader impact of the projects.
- **Adaptability** and flexibility were required to achieve impact and longer-term sustainability.
- **'Ripple effects'** could spread the outcomes beyond the limits of the project itself.

Our findings also highlight questions for future research including approaches to:

- how to define citizen science
- citizen science's relationship with participatory research the role of co-production in citizen science.

B. Researchers' perceptions of success and challenges

We found common perceptions of what worked and what didn't from the perspective of the CSEG researchers, including their reflections on the role the grant design had as an enabler or barrier to delivery.

Successes:

- High quality data were obtained across different projects.
- Many projects extended the scope of their initial ambitions through sustainable engagement.
- Citizen science methodologies resulted in positive effects on community and societal development.

Challenges:

- Limitations due to time commitments of both researchers and citizen scientists. These were compounded by the Covid-19 pandemic.
- Where projects embedded their work into specific contexts, they sometimes came across social and political contextual challenges to work with.
- The inherent dependency on citizens, with their changing needs and circumstances impacting the research process.
- The perceptions of audiences and stakeholders less familiar with citizen science, which could form a barrier to sharing findings.
- Limitations in follow-up, particularly where citizen scientist involvement was limited or anonymous.

C. Citizen scientists' voice

Unfortunately, the voice of citizen scientists was captured only via the researchers and not directly. This was due to anonymous participation protocols; deleting participant data in keeping with data protection provisions; and to avoid overburdening citizen scientists with additional engagement. Bearing this in mind, CSEG researchers reported on:

- **Citizen scientists' motivations, highlighting their** existing interest and investment in the subject matter, their desire to contribute to impact, and their drive to work with/communicate with others.
- **Citizen scientists' feedback to researchers,** giving concrete feedback on outputs, on future improvements, and on their desire to be involved in future work.
- **Citizen scientists' reflections** on their enjoyment of participation, reflecting on learning and impacts, and sharing their hopes for the future.

These three elements tell us that citizen scientists engaged not only in the subject matter of their projects, but also in their methods and outputs - and that they thought in reflective and longer-term ways about this engagement.

Recommendations

Our recommendations fall into two categories: recommendations for the design of citizen science research projects, and recommendations for the funding of projects.

Recommendations for research design

1. **Plan for learning and sharing:** clearly articulate learning aims for both researchers and citizen scientists, and engage with other researchers and practitioners to share learning about citizen science.
2. **Plan for social impact:** identify key social issues connected with the project and integrate these into the way that engagement with citizen scientists is designed.
3. **Be open to experimentation:** design for flexibility at set project stages and be open to spontaneous adaptability in response to unforeseen challenges.
4. **Emphasise relationships**: consider how relationship-building opportunities can be designed into projects from the outset; the relationships built during a citizen science project can support ongoing impact and facilitate future research.
5. **Plan for evaluation:** build plans to collect citizen scientist feedback into the research design; collect data to help identify who is and is not taking part in citizen science; and plan to collect evidence of impacts that extend beyond the duration of the project itself.

Recommendations for funding design

1. **Support consolidation as well as innovation**: allow time and resources for building and maintaining relationships; support documenting and advocating for the value of citizen science; support core infrastructure needed for successful delivery, including tools and networks.
2. **Support co-production**: allow sufficient time and resource for researchers to reach diverse participants, for citizen scientists to help design projects, and for learning between researchers, citizens, and others interested in these approaches.
3. **Support co-learning across the programme:** promote development opportunities across the entire process; build in collaboration with other grantees to share learning and best practice; provide follow-on funding to enable long-term research agendas and maintain relationships.
4. **Support longitudinal follow-up**: allow time and resources to follow up with participants or to test for social impact, where ongoing engagement from the same citizen scientists is not possible or necessary.

1. Background

The rationale

In 2019, UKRI funded 28 CSEG projects. Part of the call stated:

'Citizen science is an important way in which diverse groups of people can participate in research and innovation, whether through collecting data, analysing data, or helping researchers and innovators to develop better questions.' *(UKRI, 2020b)*

The grants aimed 'to allow researchers to develop pilot projects to build citizen science capacity into their work' (UKRI, 2020b), by offering funding of up to £20,000 to each successful project. Notable assessment criteria for proposals included:

- 'Where appropriate, quality of plans to deliver pilot citizen science activities that will inform further development of your project' indicating the longer-term aims of the CSEG funding for promoting further citizen science work beyond the funded projects themselves.
- 'A demonstrable commitment to exploring the potential of the appropriate citizen science methods for your project', highlighting the meta-outcomes of interest beyond project findings, extending into methodological considerations.
- 'A demonstrable commitment to building the appropriate partnerships to deliver your project' indicating a focus on relationships and collaborations. (UKRI, 2020b)

What projects were funded

Some 28 projects were awarded CSEG funding. However, at the time of writing (April 2022), 25 CSEG projects have produced final reports with relevant data and learning. These have been the primary focus of this review.

Initially intended to be conducted between 16 December 2019 and 30 April 2020, due to the pandemic, most projects were extended. The disruption caused by Covid-19 is further discussed in the 'challenges' section in Chapter 4.

CSEG projects spanned a broad range of topics and approaches. These can be broadly grouped under the following headings:

- Environment
- Ecology
- Physics
- Technology
- Reviewing citizen science methods
- Public health

However, it should be noted that these categories intersect, and a single project often cannot be fully located within one discipline.

Furthermore, not all the projects used citizen science to investigate a research topic utilising citizen science; some investigated citizen science itself as an approach. These projects did not recruit 'citizen scientists' in the typical way; for example, some projects ran workshops with academics and practitioners to review how citizen science is conducted in different contexts [1]– [6]. Appendix C provides further details about the affiliated departments and institutions.

Participant engagement

Projects engaged with different types of participants, through a variety of channels. Some projects were conducted online and open to anyone who chose to take part. Some focused on specific target groups, such as school students. In some projects, participation was also invited through organisations, or through interest groups.

For some projects, participation was determined geographically, reaching out to local communities in areas of interest. These localised projects were almost all in the UK, with only three projects working directly with participants from a local target area in other countries: Lebanon [7], India [4], Tanzania [8] (although other projects did include international participants, however not with this specific geographic recruitment focus). Within the UK, where projects had a geographic focus, this was driven either by the regional topic of the research (eg, focusing on a river catchment area [9] or a national park [6]), or by a specific local community interest (eg, focusing on the local community in the vicinity of the university campus [10]).

Project participant numbers varied greatly across the 25 projects, with the largest study reporting 10,000 participants [11], and the smallest studies 15 participants ([9], [10]). However, not every project report provided a clear value for their participant numbers: some report cases of engagement (rather than individuals) such as pupils from 50 schools [12] or representatives from 16 organisations [1]. From those projects where numbers were clearly stated (n=18), the mode number of participants was 15 and median 39. Participant recruitment was also often impacted by Covid-19, resulting in lower participant numbers for many studies than originally planned.

2. Our methodology

This review analyses diverse projects to collate varied insights and learning. It seeks to shed light on both practical and conceptual issues around citizen science approaches, to contribute to knowledge about citizen science as a research method, and to inform future research and funding design.

The evaluation process followed an iterative approach:

- Firstly, we reviewed the 25 CSEG projects that yielded a final report alongside additional questionnaire project summary data (ie, research outcomes data collected through researchfish).
- Secondly, we developed five case studies based on further interviews with researchers from the selected projects (sampled for diversity across the project).
- Next, we re-analysed the final reports for further insight, particularly in understanding direct feedback from citizen scientists.
- Finally, our findings and recommendations were reviewed and discussed with the researchers involved in CSEG projects in a roundtable session. This helped us refine this report.

While some of our findings pertain to 'citizen science' as a research method, we note they are contextualised to the CSEG projects. They therefore represent an approach to citizen science that was shaped by the design of this grant (eg, the emphasis on relationship-building in the grant assessment criteria).

Based on the information available to review, our evaluation did not seek to make judgements about the quality of projects, nor to assess their outputs. Where successes were identified, they were drawn from the perspectives of the researchers describing them and were not deployed in any comparison between projects. Rather, our aim was to share successes across projects to identify best practices and inform future work. Our evaluation did not include any direct input from project participants, due to barriers to reaching out to citizen scientists (discussed in the Citizen scientists' voice section of this report), however we have included reported citizen scientists' perspectives from the grant teams' final reports.

The full methodology and limitations are provided in Appendix B.

Case study project overviews

We developed case studies based on five projects, which are referenced throughout this report

1. National Trust - Stream sleuths: using fish eDNA to determine shared catchment actions

This project trialled a participatory way of finding out about species diversity in a local catchment area of the river Bure, using environmental DNA (eDNA) techniques. Extracting eDNA from river water samples can give a good overview of the species living within the water. The project involved citizen scientists recruited from local interest groups, such as angling clubs and local environment groups, who joined experts in a workshop to learn about the technique and its potential uses, and then collect water samples from different river sites.

2. University of Plymouth - GlacierMap: mapping glacier change in the Peruvian Andes

This project created a freely available online glacier mapping tool, which was used in secondary schools to enable students to learn about glacier retreat and water security in Peru. Participants included both school students from target schools, and wider online participants from across the world. Participants mapped the outlines of glaciers in satellite images presented within the online platform.

3. Imperial College London - 'My House My Rules'

This project engaged citizen scientists from the local community of the university campus in co-producing an approach to measuring indoor air pollution. Participants were engaged in co-designing the research questions, and suitable methodologies, as a first step towards larger-scale research on indoor air quality.

4. University of Bristol - Using the UK air quality archive in primary schools

This study used the Defra UK Air Quality Archive, a database with freely available air quality data, working collaboratively with teachers to design ways of using the database information to explore pollution, its causes, and its impacts. Classroom resources were used with primary school children, including an opportunity to meet the scientists.

5. University of Oxford - Co-creation of CERN OpenData projects with UK school students - pilot study

This project developed activities using the OpenData provided by the ATLAS experiment at CERN, to be used by school students for developing their scientific and technical skills. The project included a workshop, bringing together researchers and practitioners, and a pilot of the teaching materials in schools.

3. What we found

This section of the report presents findings of the thematic review of the final reports produced by the project teams, structured by theme:

A. Learning and empowerment
B. Levels of participation as different understandings of citizen science
C. Effective and sustainable citizen science

The links and interconnections between themes are also explored. This is followed by a summary of the researchers' perceptions of their projects' key challenges and successes. Finally, a review of the citizen scientists' voice as it was presented in the reports are surmised. case study findings are provided throughout this chapter, in relation to the theme or topic they can best enrich.

3.1 Learning and empowerment

This theme focuses on the ways that undertaking citizen science research yielded learning, empowerment and engagement for all involved (participants, researchers, partners, etc).

Two sub-themes illustrate different aspects of this learning and empowerment:

a. Participants' **learning within projects,** and what learning outcomes they could expect
b. **Researchers' learning through the process of engagement with citizens**, which provided insights and development.

3.1.a. Participants' learning within projects

The learning that projects were designed to provide for their participants could be conceptualised in different ways:

- Learning specific subject matter: eg, biomimicry in insects [15], or about glaciers [16].
- Learning framed as awareness-raising: eg, increasing awareness of the importance of insects in ecosystems, or raising awareness of glacier melt due to climate change.

These two kinds of learning are oriented around discipline-specific and discrete forms of information. Some forms of learning were also discipline-specific, but moved beyond discrete forms of information:

- Learning about issues and contexts: eg, learning about political information and how it is used during elections [17], or learning about climate change and its interconnected and complex impacts [14].
- Learning skills:
    - Using technology, such soil and air scanners, telescopes, or online platforms.
    - Collecting and producing data, such as gathering samples, tagging images, and following protocols.

These forms of learning were also sometimes explicitly or implicitly connected to empowerment aims; eg, learning about how political information is presented to enable participants to navigate it and make informed decisions during elections. Similarly, learning to collect data using technologies such as soil scanners was linked to increased participant autonomy in decision-making, based upon the information the scanners provided [8]. This contextual learning could also relate to awareness-raising in ways that further indicated empowerment aims, eg, in awareness of research where stated project aims could be to 'nurture a future generation who are passionate about research and innovation.' [16]. The learning of skills was also linked with learning about, and developing interest in and engagement with, the associated subject matter [18].

It is important to note these types of learning were not mutually exclusive. It is possible for a project to include learning that spans across this typology, and it is also possible for projects to be anchored within one approach to learning.

It is notable that both awareness-raising and contextualised learning were frequently linked with empowerment. A reviewer of citizen science described this methodology as, "a valuable awareness-raising tool that empowered the individuals." [5].

Some projects spanned the spectrum of learning approaches, taking a holistic view of citizen scientist learning and aiming to enable participants to become researchers. For example, bringing together scientists and local community members to conduct research as partners, so that community members could become researchers in their own right and undertake further research based on their learning during the project ([9], [19], and others).

It is important to note that researchers typically discussed their participants' learning in two framings:

1. As a planned outcome of the project.
2. As something evaluated during/after the project.

Subsequently, there were cases of both consistency (the kind of learning aimed for was also the kind of learning captured in evaluation), and divergence (evaluation captured learning beyond the project aims).

- Consistency in planned learning outcomes, and evaluation, were often centred around awareness-raising. Researchers frequently stated their aim to raise awareness around specific issues (eg, glacier melt), and then asked their participants evaluation questions around their awareness [16].
- Where there was a divergence, it tended to be in cases where the aimed-for learning was more narrowly information-oriented, and where the evaluation captured wider learning about issues and contexts. For example, researchers on one project where the aims for participant learning were not articulated beyond providing an engaging experience for them, noted their participants had questions “not only about how to complete the imagery labelling task but about the research, methods, and project design” [20], and that many participants conducted their own internet research to find out more about the context of the images they were tasked with labelling.

3.1.b. Researchers’ learning through the process of engagement with citizens

In addition to the learning of participants, the projects also yielded learning for researchers - specifically through their engagement with participants, which provided insights and development opportunities.

- **Learning about participatory research:** some projects explicitly aimed to learn about participatory research approaches, and others, which did not have this as a stated aim, nonetheless found new insights about co-production, participation and public engagement emerging. For example, some researchers noted their experiences of learning to communicate with different audiences such as children, or to adapt their work styles to better suit their participants (eg [12]). Within this, some learning from 1.a. (levels of learning for citizen scientists) can also be seen, where researchers learned from their participants what the participants themselves wanted to learn.
- **Learning about specific local contexts**: many researchers articulated learning about local needs and their specific research context, without this necessarily being a stated aim of their research. For example, setting out to teach participants to use a technology, and learning from participants how best to adapt this technology within their environment [8]

This learning was described as taking place across research teams, including students engaged as researchers on the projects, early career researchers, and project leads. In some cases, the researchers’ learning was also captured, with the aim of sharing it further among the research community.

Joint learning
Case study 3 – ‘My House My Rules’

As part of this co-designed project, researchers and citizen scientists learned from one another.

The experience of engaging with the citizen scientists was reported to have *“broadened our researchers’ horizons”*. This broadening of perspectives was shared among the wider research team beyond those directly engaged in the project, enabling learning to be shared about participatory research among colleagues. As a result, an understanding of participatory research is “certainly embedded within the broader group now”.

Furthermore, part of the project was focused on citizen scientists’ learning as *“they need to have a basic understanding and awareness of what the air pollution problem is, before we actually start looking into how we can investigate this further and start looking into solutions”*. Raising awareness and understanding were key project aims, underpinning the co-design of further research.

Taken together, this demonstrates a two-way learning process between researchers and citizen scientists. Researchers were able to share their knowledge of indoor air pollution, and raise citizen scientists’ engagement and awareness of these issues. Meanwhile, citizen scientists were able to share their knowledge of local contexts and raise researchers’ awareness of collaborative practices.

3.2 Levels of participation as different understandings of ‘citizen science’

This theme consists of three component sub-themes, which demonstrate different approaches to participation, and form different ways of conceptualising what citizen science means.

Sub-theme (a) portrays an understanding of citizen science without co-production being necessary, (b) portrays an understanding of citizen science to which co-production is crucial, (c) highlights how understanding can shift from (a) to (b). This theme therefore articulates how ‘citizen science’ can have different meanings to different researchers, as well highlighting the liminal space between different understandings of citizen science and their scope for transformation.

The way these sub-themes have been formulated foregrounds participants. The differences in understanding of what citizen science can mean are anchored around participants' roles within each project.

3.2.a. Citizen scientists as a source of data

One understanding of what 'citizen science' means was that of large-scale data collection, enabled by citizen scientists as sources of data. This represents citizen science as a form of crowdsourcing.

Examples of participants' roles:

- Collecting samples, for example harvesting yeast and sending samples to the researchers [21].
- Classifying data, for example labelling images to create training data for machine learning algorithms (eg [11]).
- Piloting technology, for example trialling a virtual reality headset [15] or beta-testing an application [22].

As such, citizen scientists provide data-oriented services to researchers, expanding the research team's capacity to create datasets, organise data, or test presentations of data.

This approach to citizen science was seen as beneficial to researchers through this broadening of data capacities, but also conferred broader benefits such as reaching a wider participant sample, breaking down geographical barriers, and in some cases increasing the speed of time-critical research (for example in tagging images for humanitarian aid in disaster contexts, [11]).

There was an emphasis on egalitarianism, diversity, and inclusivity often associated with citizen scientists working with data on a large scale. For example, in a project where many participants tagged images of rural housing in the global south, researchers noted that having an online crowdsourcing platform enabled wider recruitment beyond only Western perspectives. However, this inclusivity was typically valued by researchers with recourse to the data: 'diversity of opinions was useful to improving data quality' [20], which demonstrates how this understanding of citizen science places the data first, and participants are understood in their relationship to the data.

3.2.b. Citizen scientists as co-producers

For some research projects, 'citizen science' was conceptualised as co-production, and 'citizen scientists' were understood to be collaborators in the research process. This gave participants decision-making and collaborative roles within the research projects, although the levels of co-production were variable.

Some examples of different participation:

- Involvement in discrete stages of the research, such as taking part in a workshop to inform the next stages of the project, or through consultation to refine research plans. For example, researchers sought the most appropriate translation of key terminology by consulting the community prior to data collection, “to both hear recommendations of appropriate words and to gauge some of their interest in the concept itself” [7].

- Involvement throughout the research process, from planning through to data collection and output creation and dissemination. For example “actively involving citizens into the co-design of research questions and feasible methodologies for data gathering, creating a sense of collective ownership for those involved in the process, and ensuring that the outcomes meet both the researchers’ aims, and local residents’ needs and expectations.” [10]

- Involvement designed to be long-term, extensive beyond the timeframe or scope of the research project, where the research project is designed to co-produce learning and engagement to drive on-going research by the participants instilling: “high level of enthusiasm for the method and for continuing” [9].

Where co-production was targeted within specific stages of the research process, this was seen as beneficial for designing research in the most appropriate manner for stakeholders (such as the participants themselves, but also their wider communities). Participant involvement in decision-making was seen as beneficial for refining methodological approaches to make the research process operate smoothly, for refining the relevance of the research in line with participants’ priorities, and thereby yielding greater impact in outputs with higher levels of engagement from target audiences. For example, “the extent to which a simple conversation about where to take samples unlocked such a rich discussion about issues in the catchment was surprising and highlighted the value of local knowledge in designing a sampling programme.” [9]

In more systematically co-produced cases, these benefits were accompanied by a sense of discovery enabled by openness to participants’ input. For example, enabling flexibility to steer projects towards outcomes that had not initially been planned, such as public policy outputs suggested and driven by participants (eg [6], [19]). Diversity of opinion was also valued as a source of enrichment to the research, for example, “the mixture of energy specialists and local community organisers provided for a richer discussion in which different perspectives were shared” [7]. This valuing of diversity was not anchored to specific desired outcomes, but integral to the research.

It is also notable that researchers who understood citizen science to be *co-production also understood their own role as researchers differently, eg,* "as a facilitator helping to create the conditions for discussion and building the group's capacity to define a research question and design the monitoring methodology." [10]

3.2.c. Shifting understandings of participation

The previous two sub-themes were not always mutually exclusive, and some projects operated in a spectrum between these understandings of citizen science. In some cases, researchers' approaches to co-production, and their understandings of citizen science, were altered through the research process.

Researchers were prompted to diverge from their plans and increase the co-production they engaged in eg:

- Increased involvement driven by participants. For example, researchers finding their planned activities were not needed as participants were able to understand more than had been anticipated [9].
- Researchers responding to challenges such as low participant engagement, for example, in uptake of technology, by seeking participants' input and revising or co-designing methods to be more suitable [8].
- Researchers coming to understand complexities and disparities in their research, and being motivated to engage, or hand power to, participants in order to address contextual issues - eg, identifying issues around western cultural models when working in the global south, and seeking to use co-production approaches to empower local innovation [8].

In some cases, higher levels of co-production were planned but reduced or cancelled due to unforeseen circumstances, such as the Covid-19 pandemic. However, it is noteworthy that across the 25 projects reviewed, co-production was not reduced in response to participants' capacities or the aims of the research.

Moving towards increased co-production was described by researchers as having positive results. These included increased engagement by participants, a greater perception of legitimacy of the research by stakeholders, and increased quality of research methods through better suitability to local contexts and to participants' needs; ultimately yielding higher quality results. These shifts in approach also informed researchers' learning.

Shifting understandings of participation
Case study 2 – GlacierMap

This project was conceived primarily from the perspective of glacier mapping, with a core aim being the creation of a glacier inventory. While engagement with participants was an integral part of creating the inventory, their engagement was not conceptualised independently of their data input. However, during the project the researchers' understanding of citizen science underwent a shift:

"Before starting the project, I probably thought it was more along the lines of what you think when you do big data-collection missions, maybe like the RSPB Birdwatch, where it's very much citizens participating and collecting data. But for us, the focus then became [citizen scientists] actually contributing towards analysis or knowledge, creating knowledge and allowing us to try to understand what information participants might know, and be more interested in. But also, for us to try and give more information."

Thus, what citizen science meant to the researchers altered, moving away from previous archetypes and towards foregrounding the creation of knowledge and participants' interests. This change did align with the initial project aims, but resulted in a re-weighting of those aims, such that the educational impact of the project became the primary consideration:

"The primary aim became more about education, awareness and understanding what drives people to be engaged with climate science [...] what became much less important was the quality of the data they generated."

This shows how a citizen science project can be designed with data at the forefront, but shift towards a participant-centred approach through engaging with citizen scientists and learning about their interests and motivations.

How do themes on learning and participation relate?

Themes 1 and 2, articulating approaches to learning and to co-production, have many parallels and can be mapped against one another. Firstly, sub-theme 3.1.a. captured different levels of learning that were described in the project reports:

- Learning specific subject matter
- Learning framed as awareness-raising
- Learning about issues and contexts
- Learning skills
- Learning to be a researcher

Secondly, sub-theme 3.2.b. described different degrees of co-production:

- Involvement in discrete stages of the research, eg, consultation
- Involvement throughout the research process, from planning, through to data collection, and output creation and dissemination
- Involvement designed to be long-term, conceived of as extensive beyond the timeframe or scope of the research project

It may be that different levels of learning, and degrees of co-production, can be mapped against each other, forming a gradient from more subject-matter oriented learning and more isolated co-production, through learning to be a researcher, aligning with longer-term participation. Some indication of this alignment can be seen in the reports and case studies, for example learning about specific subject matter was associated with discrete instances of engagement in studies that only engaged participants in one-off activities, eg [15]. Furthermore, sub-theme 3.2.c. describes shifts towards understanding citizen science as participation. This was also associated with shifting understanding of learning, as seen in case study 2, where participants' learning moved towards deepening awareness, into contextualization, and skill development became the central focus as researchers foregrounded participation.

The connections between different forms of learning, and different levels of participation, may offer an interesting avenue for future evaluative research investigating citizen science approaches.

3.3 Effective and sustainable citizen science

This theme encompasses ways that citizen science was designed and conducted to be sustainable, and to meet the needs and expectations of those involved. Three sub themes highlight important nuance within the efficacy and sustainability of citizen science approaches:

a. **Social, political and issue engagement as an outcome,** highlighting the broad impact of the projects.

b. **Adaptability,** illustrating how flexibility was achieved to ensure impact and longer-term suitability.
c. '**Ripple effects'**, showing researchers' perceptions and hopes of the ways in which engagement with their projects could spread outcomes beyond the limits of the project itself.

3.3.a. Political, social, and issue engagement as outcomes

By engaging participants in projects relevant to social and political issues, taking part in citizen science became a springboard for ongoing interest and further, longer-term use of the skills and information learned. This included:

- Use of skills to further social and community aims: "we noticed the development of locally-embedded scientific interests and skills that foster stronger community ownership and engagement in action research." [8]
- Social and political impact as a long-term outcome, for example facilitating ongoing consultation between participants and policymakers, eg [19].
- Ongoing engagement by participants with social and scientific issues, for example climate change, air quality, pollution, etc.

These outcomes resulted from the deep interconnection between scientific and social aspects of the project topics, which may be seen as a key facet of citizen science, as articulated by one interviewee, "There are all sorts of other important issues, tangled up with citizen science, that go way beyond science." However, it should be noted that not all project reports evidenced this interplay, with some focused entirely on scientific and technological aims, and topics less obviously linked to social issues, with little participant interaction (eg, beta-testing a super luminous supernovae application with fully anonymous online volunteer participants [22]).

As well as working with participants, another form of ongoing engagement resulting from the participatory projects was seen in researchers' approaches, and in projects' contribution to wider research agendas. This included broadening interest in participatory research, and shaping participation opportunities, to make future research more inclusive (eg, in identifying participation barriers [23], or developing co-produced research approaches [10]). In this way, research agendas could become more oriented around social issues.

This final point was explicitly an aim in those studies that brought together researchers and practitioners to identify best practices in citizen science: "we were

able to offer insight into citizen science best practices which we hope will be useful to the project participants moving forward" [19].

These different forms of engagement indicate a value in citizen science approaches that can extend beyond the timeframes of the projects themselves, both for participants and for researchers.

3.3.b. Adaptability

Projects involved different levels of, and approaches to, adaptability in their design. As these projects took place during the Covid-19 pandemic, all faced circumstances that necessitated adaptation, therefore creating a set of case studies of different responses. This revealed different forms of adaptability across the projects, including:

- Spontaneous adaptability was described in some projects, where unexpected events and participant input prompted researchers to shift their approaches.
- Designed-for adaptability was also featured in projects, where plans were intentionally contingent upon participant input, for example planning participant engagement that would inform next project stages [7].
- Project designs limiting adaptability were also noted in the reports, typically where participant interaction restricted further engagement. For example, in online data collection, some feedback surveys had lower uptake than desired and follow-up was not possible (eg [16], [24]).

In some cases, adaptation to challenges such as Covid-19 resulted in projects identifying new, additional activities or resources they could produce in response to the changing situation. This necessitated changes in their planning (eg, creating a book for school children on biotechnology [21]). In others, adapting to challenges initially appeared negative, but resulted in improvement, for example the pandemic necessitating a reduced number of participants, but "fewer participants were each able to undertake a more detailed interaction providing a true and valuable two-way exchange of information." [18]**.** This demonstrates the value of adaptability in the face of negative circumstances for these projects.

Furthermore, it should be noted that this sub-theme links to sub-theme 3.2.c., as cases where researchers' understandings of citizen science shifted are also cases of adaptability. These instances demonstrate the importance of researchers' personal adaptability.

Adaptability
Case study 5 – CERN OpenData

This project was seriously impacted by the Covid-19 pandemic, which necessitated adaptation. Adaptability was also required in response to workshop input from researchers and practitioners. The project team explored “how did you make sure that you could get to a co-creation process rather than just a dictation process or a learning process”, and how they could apply this to their own research design.

By adapting the project and conducting a re-planned version of it, researchers were able to learn, and design further future research steps: “What we learned has definitely been employed by us and deployed by us in the larger scale tests that are ongoing. And we've been skilling up in a sort of series of steps.” This demonstrates the value of adaptability not only within a single project, but across a wider research agenda in iterative studies.

Indeed, for the researchers, adaptability was articulated as a key factor in successful citizen science approaches: “Doing citizen science projects is an experiment in its own right. And it requires you to be willing to adapt and to change and to pilot and to try things out, and to adapt when they don't work and see what those were.”

The relationships built during the project were articulated by researchers as a key success, resulting in longer-term sustainability of outcomes and further studies. Via workshops with researchers and practitioners, the project team found others interested in conducting similar work:

“We certainly didn't have all the answers ourselves. But the project was really helpful in helping us work out who were the people that had bits of the jigsaw that we could put together.”

Furthermore, the teaching materials made during the project (such as coding workbooks), can be used more widely, and adapted further. The materials remain in use by teachers, with a forum facilitating ongoing engagement beyond the project itself. When these materials were brought to CERN “there was recognition that they were a much more accessible way into the open data than what had been used so far”, demonstrating the value of designing for accessibility for citizen scientists and broader audiences.

3.3.c. ‘Ripple effects’

As has been described above, longer-term impact was an aim of many of the projects. However, in the case study interviews, researchers articulated informal observations of ‘ripple effects’ spreading the engagement and learning from participants to their wider communities broadening change and impact.

Examples include research activities enthusing participants, and this enthusiasm was believed by the researchers to have the potential to spread in the community: “The citizen scientists probably went home and told their families and people they live with, their friends, about how this technique could work, because they really were enthused about the science bit of it.” (Case study 1: Stream Sleuths).

In some cases ripple effects could include behavioural changes, such as in case study 4: UK Air Quality Archive: “a whole bunch of parents walk their children to school, or don't drive them to school”, because of their engagement with air quality issues. Should such changes in behaviour take place “that in itself would have a massive impact on improving air quality.”

While such ripple effects would require follow-up investigation, some case studies, such as ‘My House My Rules’, showed indicators of ongoing impacts; eg, a participant communicated with the research team more than a year after the study to ask questions about air quality in local schools. For the researchers, this is “an example of how learning evolves over a period of time”, and how this may have knock-on effects if community members challenge schools and other institutions to improve air quality. For the researchers, it is positive to consider the learning participants experienced in one project “propagating outward like that”.

Such ripple effects all require further investigation, but these examples demonstrate the potential for participant’s experiences of citizen science to drive longer-term outcomes.

How do themes on participation and sustainability and adaptability relate?

Sub-theme 3.2.b. included an aim of developing a research design that participants could own and continue themselves, beyond the timeframe of the research project. This connects the theme of understanding citizen science as co-production to the theme of sustainability in research design. This is seen in case study 3, where sustainability was the aim of-designing of the research approach, such that it could be successfully proposed for further funding and carried out in a way that would work for the local community participants. In the reports, there are many cases where the co-design of approaches enabled participants to better absorb learning,

utilise technologies, and take ownership of the studies, resulting in ongoing use of their learning and resources (for example [8], [9], [14]).

Sub-theme 3.3.b. drew a distinction between spontaneous adaptability and designed-for adaptability. This aligns with the different types of participation found in sub-theme 3.2.b. (ie, involvement in discrete stages; throughout the research process; and extensive beyond the timeframe or scope of the research). Involving participants in discrete stages of the research to inform specific aspects is a form of designed-for adaptability. Meanwhile, involving participants in co-design throughout the research involves spontaneous adaptability, as it is not possible to pre-determine when and how they will seek to change how the research is conducted or what directions it ought to take.

This demonstrates how different approaches to participation relate to different levels of sustainability, and to different approaches to adaptability. Further investigation of these connections in broader citizen science approaches would be an interesting direction for future evaluation.

Open questions

This evaluative review process highlighted various findings, but also raised questions. Some point to ongoing research issues and debates, and do not have direct answers. Here, we highlight questions as prompts for future research about citizen science approaches.

How do citizen science and co-production relate?

Based upon the 25 projects we reviewed, co-production was not a necessary ingredient of citizen science, nor was it a necessary ingredient for success. Many projects included no co-production, but achieved various successes, and indeed the low-stakes nature of the participants' engagement in these projects was an important feature of their design, and a contributor to that success.

Conversely, where projects were highly collaborative and involved participation in co-design decision-making, it can become tricky to identify what makes these different from other kinds of participatory research that is not labelled as 'citizen science'. Questions arise around the categorisation of different participatory research approaches, and how they relate to each other. For instance, is 'participatory research' an umbrella term, with citizen science sometimes falling with it? Or is 'citizen science' the broader term with 'participatory research' describing a subsection of it? This brings us to our next open question on how citizen science is defined.

What is ‘citizen science’?

Each of the case study interviews opened with a question asking the researcher(s) to provide their own definition of citizen science.

Their answers included:

“Citizen science is a ‘spectrum’ from data collection to participation.”

“Citizen science is participation in research which contributes to knowledge construction”

“Citizen science is like a two-way conversation around the issue”

“Citizen science is an opportunity for people to be an active part of the research process.”

“Citizen science is much broader than just science. There are all sorts of other important issues, tangled up with citizen science, that go way beyond science”

“Engaging a variety of stakeholders from the general public in research [...] as a collaborative project”

“[It] has to be two-way [and involve] learning something from [participants]”

“It's involving non-professional scientists in the scientific endeavour in the broader sense. So, it's everything from coming up with proposals for interesting scientific experiments to perform, to gathering data for them, to analysing that data, to reporting on the outcomes of what they say.”

“Everything involving research done by people whose job it isn't to do research”

A definition of citizen science that provides necessary and sufficient conditions for any given project is almost certainly unobtainable. It may be that citizen science is better thought of as a ‘cluster concept’, or perhaps as a term that encompasses several families of approaches.

4. Researchers' perceptions of challenges and successes

Researchers articulated various challenges during their research, and identified diverse successes resulting from their projects. In identifying common challenges and successes, we have focused on the researchers' perceptions, and have not sought to classify success or failure ourselves as reviewers.

Challenges

The impact of Covid-19

The CSEG projects took place during the Covid-19 pandemic, with most planning to commence their participant interactions in early 2020, during the UK's first national lockdown. This impacted all projects.

Project teams worked to re-plan events and re-purpose materials for online delivery, but for most this was not a smooth transition and could not be seen as an equivalent to their original planning. This led some researchers to postpone their citizen scientists' engagement (eg [17]), reduce engagement events (eg [23]), and others to reduce their participant numbers (eg [12]). The impact of the pandemic upon the CSEG projects cannot be over-stressed, and the adaptability and fortitude of the project teams was significant.

Challenges related to specific social and political contexts

Challenges in the wider social/political context were experienced by researchers whose projects embedded them in specific context, particularly where their project aimed to drive change, including challenges in reaching participants, in communicating with policymakers, and in adapting to local needs (eg [7], [8], [19]). This was, most evidently, the case for researchers working with participants who were less privileged or did not come from the dominant western background within which most research approaches are anchored (eg [7], [8]): "For example, many citizen science tools are based on the assumption that everyone has access to internet and technology, which is often not the case for all residents in rural East African communities."

To resolve these challenges, researchers worked collaboratively with their participants, for instance training local researchers to use certain technology [8], or working to adapt language to be meaningful and relevant in the local context [7]. In these cases, challenges were successfully overcome, and the co-produced process was a key project success.

Project dependencies

Further challenges included the dependency on project partners and citizen scientists when conducting participatory research. Projects had to suit participants' schedules, which could conflict with the idealised project proposals. This was especially the case in projects working with schools, where delivery of engagement sessions had to meet school timetabling needs (eg [12], [16], [23]). Some projects also depended on external events (for example elections [17]). These dependencies could cause challenges where the project timeline was restrictive.

Communicating the value of citizen science approaches

Communicating the value of citizen science approaches could also be a challenge, for example, "one organisation told us they would only consider using citizen science-derived data if it had been published in a peer-reviewed journal." [19] However, this challenge also demonstrates the value of sharing citizen science best practice widely, as, "this highlights the importance of collaborations between academic researchers with citizen science practitioners - our approach of bringing policy stakeholders to the conversation worked very well" *[*19] Indeed, as discussed in the subsequent section on successes, data collected through citizen science approaches is often found to be of excellent quality and is highly valued as a key project success by researchers.

Obtaining feedback and follow-up engagement

Obtaining feedback and engaging in follow-up engagement with participants could be a challenge where this was not planned into the initial project design. This Is discussed further in the "Citizen scientists' voice" section.

The grant design

The way the CSEG funding was designed also posed challenges for researchers. While the impacts of the Covid-19 pandemic were mitigated through grant extensions, there were nonetheless pressures which the grant timeframe posed.

- **Rigidity in start/end dates:** Fixed start and end dates could cause participation issues. For example, CSEG projects commencing before the Christmas period did not allow for immediate communication with some participant types (such as schools).
- **Favouring established relationships and research agendas:** The short timeframe also placed limitations on the extent to which relationships could be developed, and co-design achieved with participants. Some CSEG projects were conducted as part of a broader research agenda. These cases had a relative advantage in the extent to which they could deploy existing collaborations and rely upon firm relationships already in place, or in the extent to which they could use their CSEG grant wholly dedicated to building relationships for future work.
- **Disparity between new and established research:** In cases where the CSEG grant was used to undertake a more 'complete' project, including relationship building and research activities, the timescale posed a far greater challenge.
- **Limiting follow-up:** The project timeframe also limited the extent to which follow-up engagement with participants, including evaluation, could be conducted.
- **Limiting dissemination:** Short project timeframes may also have restricted the communication activities undertaken by researchers to share their findings, which may pose an issue for the advocacy of citizen science.
- **Disparity in qualitative and quantitative evaluation:** As qualitative data analysis can be more time-consuming than quantitative analysis for participant feedback, shorter timeframes may make qualitative approaches to evaluation less feasible.

Additionally, the window of time between the release of the funding call to its deadline caused constraint. Again, the brevity of time for writing a proposal favoured researchers engaged in broader programmes of work, as they were potentially able to deploy existing materials, and rely upon existing networks, to put together a proposal rapidly. A short period of time in which to develop a project idea and design an approach may also favour less innovative approaches, making it more likely for researchers to propose work with easier to reach groups.

It is notable that challenges posed by the design of the grant were oriented around time, rather than the grant amount. However, while citizen science can be seen as a 'cost effective' method, the need for resourcing should not be underestimated. Several of the CSEG projects fitted into a larger research agenda, with researchers 'interleaving' various grants to support different components of their work, ultimately aiming to conduct cohesive research with a sustained citizen science infrastructure. This implies a need for greater resourcing security for larger-scale ongoing citizen science research agendas, to sustain their broader work as it builds towards stronger networking, resulting in richer findings. This is further discussed in the recommendations section of this report.

Successes

Data opportunities through citizen science

In some reports, data obtained through the practice of citizen science were identified as of very high quality and this was seen as a key success of the project (eg [9], [14], [20]).

Data opportunities
Case study 1 – Stream Sleuths

This project primarily focused on participant engagement and co-production, with the data being collected also an important consideration, but not the primary aim of the work. As such, it demonstrates a case of very high-quality data being obtained from a primarily co-production-oriented methodology.

Firstly, this was seen in terms of the citizen scientists' ability to accurately follow the sampling method and collect uncontaminated, useful water samples:

"I was really pleased with the quality of the data that came back on the fish communities. The fact that all of the samples apart from one were, in effect, fully valid samples - you couldn't have hoped for anything better than that."

This supports the researchers' experience of the speed and competency with which their participants learned about the technique and showcases the skills they developed.

Secondly, in addition to the quality of the data, this project exemplifies the usefulness of data collected via citizen participation: "I think we were confident we would get some reasonably good data. But I don't think we knew that it would necessarily tell us anything new that we didn't know about the river system. And actually, it did: it kind of unlocked a few things that we didn't know about. So, I think that was a secondary kind of consideration, but it was a bonus."

Here, we can see how even where the data is not the primary emphasis of the project design, through engaging in co-produced citizen science new insight can be gained from the data that is collected.

Sustainability of citizen science

In some CSEG projects, researchers said sustainability had become a surprising and unforeseen priority, furthering the scope of their work (eg [14]).

Furthermore, many projects found that citizen science methodologies could benefit community and societal development. Linking to the sub-theme 3.3.a., these successes were articulated in terms of wider engagement at community and societal level. In some projects, people gained new skills and adopted them into their own initiatives that directly affected the community, for instance “the citizen science approach provided local farmers an opportunity to circumvent traditional power and knowledge inequities” *[*8].

Where social impacts of projects were found, some researchers were able to develop their citizen science methodologies ‘actively’ by measuring the initial successes and developing it further to allow greater community and societal development (eg [7], [8], [10], [19]).

The grant design

Just as the design of the CSEG funding could pose challenges, it also enabled project successes. A key advantage was its ‘exploration’ focus, as this offered a highly valued opportunity to try different approaches in an experimental manner.

Citizen science was perceived as a high value-for-money method, with a relatively small grant shown to have great impact through engagement - including the potential ‘ripple effects generated through citizen scientists passing on their learning to others around them, and more clearly substantiated impacts, such as sharing learning through developing relationships and networks. Projects where citizen scientists continue to use the skills they developed have very large return for a small investment over the long term. The relationships built continue to support researchers’ work, contributing to further research.

For some projects, the CSEG grant enabled the development of relationships and approaches that have been incorporated into further research projects very explicitly. As one interviewee described: “we interleave with lots of other grants from other places in order to give us that continuity, and which you need to build up a programme like this”.

5. Citizen scientists' voice

To understand citizen science approaches, their impacts, successes, and challenges, the perspectives of the participants who took part are equally important. In this section, we collate as much information as was available from the point of view of the participants across the projects.

Learning from limitations in gathering citizen scientists' input

As part of this evaluation, a survey was distributed via the CSEG researchers, seeking to gather participant experiences and invite participants to take part in a focus group, with incentives offered. However, as only a single participant completed the survey, our citizen scientist engagement was ultimately unsuccessful. We learned this was because of:

- anonymous participation: many projects maintained participant anonymity and did not therefore collect contact information which could be used to invite participation.
- deleted data: many projects deleted their participants' data to be compliant with GDPR/ethics regulations.
- participant burden: projects that required ongoing engagement with the same participants did not wish to over-burden them with additional communications and requests for their time.

These factors limiting follow-up engagement with project participants provide lessons for future longitudinal evaluation design.

For our evaluation work, further attempts to communicate with participants would not have been appropriate. We therefore adapted our design and refocused on the final project reports. We re-analysed these reports, seeking evidence of 'participant voice' contained within them, such as quotations from participants, summaries of survey data, or anecdotal evidence of participants' views and experiences.

However, not all reports featured descriptions of participant voice - in some cases because it had not been captured, and in others because, while it may have been captured, it was not reported. As the available data - in the form of survey response summaries, selected quotations, and researchers' descriptions of their interactions with participants - is limited, these findings offer some indication (but not a full picture) of participant experiences.

Participants’ voice in the project reports

Collection of participant views

The primary means of collecting participant input as described in the project reports were surveys:

- Quantitative survey data: using Likert scales to rate knowledge, interest, etc.
- Qualitative survey data: using open text boxes to elicit responses.

Pre-and post-project surveys were often used to compare participant knowledge about, and engagement with the subject matter, before and after participants took part (eg [13]). However, researchers noted limitations in this approach, particularly where feedback forms were used in conjunction with online activities, as low response rates were often recorded (eg [16], [24]).

Additional indications of participants’ voice were reported by researchers as arising informally, through individual communication:

- Communications from participants - for example, email feedback on a manuscript resulting from the project [19].
- Informally, in dialogue with researchers.

From these means of collecting feedback and reporting, participants' perspectives, some sense of their motivations for taking part in the projects, their feedback on the projects, and their broader reflections can be obtained.

Collection of participant views
Case study 2 – GlacierMap

This project found that quantitative and qualitative survey responses each gave a different picture of participants’ learning and engagement. As participants tended to rank their existing engagement and knowledge highly prior to the glacier mapping activity, the change to the post-activity comparison was very small.

However, the researchers found that qualitative data offered a greater insight: “When we looked at the qualitative data in the feedback, that's where we actually discovered a lot [...] In the qualitative responses you really saw the breadth of knowledge change”. While this is only one case study, it nonetheless suggests that gathering qualitative responses adds value in understanding participants’ knowledge development.

Motivations

Existing interest and investment in the issues the projects focused on were key motivations for participation. For example, in one questionnaire a participant wrote, “90% of our fishing club are confirmed naturalists” *[*9]

This existing engagement with issues also linked to a desire to contribute to the impact of the projects, and broader scientific endeavour. For example, quantitative survey data showed main motivators as “a desire to contribute to projects with real world impact (90.8% reporting [agreeing]) and a desire to contribute to scientific research (78.9% reporting [agreeing])” [20]; with participants describing practical impacts as an important aim in taking part: “I’m involved because it’s important to clean up the river” [9].

Finally, a desire to work with others, including interaction and communication with other participants as well as with researchers, formed a motivation for taking part. One participant described wanting to, "hear the opinions of others; hear from researchers with the background and findings, being able to have my say” [10].

Feedback

Feedback gathered from participants about the projects included concrete suggestions for future improvements, such as changes to the design of online platforms and tools. For example, “It was a great idea to put it online and I loved the approaches but sadly it was really hard to type as the boxes kept freezing and mumping out as different people typed, so I could not develop my idea as well as I wanted” [6].

Feedback was also provided on the nature of the learning activities they engaged in, and how they felt their learning could be better facilitated or stretched. For example, a participant describing how, “The game was fun, yet the link between quantum physics and the puzzles wasn’t as apparent” [24].

In some cases, participants also provided feedback on project outputs, such as being included in the authorship of papers and providing input into the drafting process: “I think this [draft manuscript] looks fantastic and will be an extremely useful paper and reference for us.” [19]

Finally, some participants offered feedback on a desire for future work, with suggestions for how such engagement could take place. For example: “[I] would love the opportunity to repeat testing on a semi-regular basis” [9]. In some cases, participants gave feedback on their own commitment to continue the work

themselves: “Participants from each site have said that they will continue to upload their species records and visit the sites regularly.” [14].

Reflections

Participants shared their experiences of the projects, and what it had been like for them to take part. Many of these reflections included aspects of their project engagement which they had particularly enjoyed. For example: “Several respondents also expressed that they enjoyed the researcher engagement on project forums.“ [20] Often, this enjoyment was connected to the learning activities of the projects, for example a student describing, “During the game, it made me a lot more interested in it. In school, I was never interested, and physics was my least favourite subject in school but here I was interested in knowing what was happening after I finished. I like trying something out rather than being spoken at.” [24].

Many participants reflected on what they had learned through their project engagement, in some cases gaining new insight into current issues such as: “I learned that even in today's world there are still many people living without things that we consider basic necessities like electricity.” [20]. Some participants’ learning was also linked to potential change in their behaviour: “Four of the respondents felt that they had increased their knowledge and awareness of air pollution as a result of participating in the study, with respondents reporting that they would consider changing their behaviours as a result of participating.” [13]

Finally, for many participants, reflection was tied to the impacts of the project, and their contribution through taking part: “Contribution to a worthwhile endeavour’ / ‘More appreciation of the diversity of species in the area” [9]. Reflections on the impacts of projects also came from practitioners and policy-workers who had engaged with the projects, as is exemplified in a communication from the Environment Agency: “It was useful to share thoughts from a regulatory perspective on developing a citizen science approach to plastic pollution” [19]. Connecting to the previously discussed findings on projects successes, including beneficial impacts on community and societal development, participants also reflected on their conversations with the researchers: “Through informal conversations, participants also expressed their strong sense of responsibility towards their community, particularly to future generations (many of them referring to children and grandchildren)” [10].

Lack of participant feedback

Not all project reports included any participant voice, and indeed some project reports included insights into why this may not have been captured:

- Omission by design: some projects actively opted for participant anonymity as the most appropriate design for their research: “The way the citizen science element is embedded in www.openelections.ac.uk does not, however, lend itself to comments from participants. We have, by design, left the uploading and coding of the election leaflets anonymous.” [*17]*
- Learning for future work: For some projects, participant input was only identified as something that would have been valuable once it was no longer possible to capture. For instance: “We wish we had collected information about this, but it was not part of our study design. A lesson learnt, as such insight would inform our future practices.” [25]

These examples, taken in conjunction with the barriers to participant communication identified through this evaluation project, demonstrate how capturing participant voice requires feedback collection and further communication as part of project design, barring cases where participant anonymity is required.

6. Recommendations for future citizen science approaches

Recommendations have been drawn from the findings presented in this report. We have sought practical and concrete considerations that may be useful for those designing research projects or funding calls. The recommendations presented here are suggestions to consider when approaching future citizen science projects; they are not exhaustive, nor will they be suitable for all citizen science research.

To frame recommendations for future approaches that could bolster the efficacy and value of citizen science research, it is firstly useful to summarise the ways in which this high value emerged through our review:

- **Integrating scientific and social themes:** citizen science inherently connected scientific topics into broader social impacts and considerations, and the interlinked social and scientific issues formed a key facet of participant learning and ongoing engagement.
- **Establishing relationships:** researchers and participants formed relationships both with one another and amongst themselves, and these relationships became the basis for ongoing work to build upon the individual projects. Therefore, any single project that entailed relationship-building established grounds for ongoing future output.
- **Generating high-quality data:** researchers described a very high quality of data obtained through citizen science approaches. As citizen science has the potential to include large numbers of participants, there is potential for significant volumes of quality data to be generated with relatively low costs.
- **Generating materials for reuse:** several projects created materials that could be redeployed further. For example, teaching materials that could be adapted and used by other teachers in future lessons.
- **Potential ripple effects:** researchers observed indications of ripple effects extending from their projects. These included:
    - **Reaching a broader audience:** as citizen scientists discussed their experiences with their families, communities, and wider networks, they shared the information learned through the projects widely.

    - **Behavioural change:** as citizen scientists engaged with issues addressed by their projects, their personal behaviours may have shifted, thus contributed to tackling these issues.

These projects indicate many ways that relatively small-scale citizen science projects can lead to impact. This suggests high value from relatively small grants, but further research is required to explore this in more detail.

Recommendations for research design

While it is vital to recognise that each citizen science project encompasses different aims, different conceptions of citizen science, and different subject areas, participants, and issues of focus, the following recommendations have emerged as useful considerations for researchers designing citizen science projects.

- **Plan for learning and sharing**
  It may be helpful to articulate levels of learning aimed for within a project from its conception, and to consider where further kinds of learning could be included, to offer participants as rich a learning experience as possible. This might include:
    - Considering researcher learning at the planning stage, including ways of sharing learning from team members who are engaging with participants to the wider team or department.
    - Holding workshops with researchers and practitioners to share learning about citizen science can both help to identify best practice, and to build networks and relationships.
- **Plan for social impact**
  Identifying key social issues connected with the subject area of the project, and integrating these into the way engagement with participants is designed, can help enrich the citizen scientists' experience by meeting their potential motivations.
- **Be open to experimentation**
  Just as planning for a well-designed project is important, so is adaptability in citizen science. Including openness in research design can enable innovative directions to emerge.
    - Designed-in adaptability can be included in set project stages, for example by bringing in participants to co-design specific elements of the research projects.

    - Openness to spontaneous adaptability can help meet unforeseen challenges, and consider unpredicted participant input.

- **Emphasise relationships**
  The relationships built during a citizen science project can form the basis of ongoing impact and facilitate future research. This can include relationships with participants, organisations such as community groups and professional organisations, and other researchers. Considering relationship-building opportunities, and how these can be designed into projects from the outset, may be beneficial.
- **Plan for evaluation**
  Including plans to collect feedback in research design can help avoid unnecessary barriers later on. This includes obtaining ethical approval for collecting and using participants' data to contact them for feedback in a data protection-compliant manner.
    - Where participant anonymity is maintained and no contact information is collected, this should be a positive choice driven by the particulars of the research project.
    - The inclusion of qualitative data can help enrich the feedback that is obtained from participants. However, this requires additional analysis time.
    - Where impacts are thought to extend beyond the duration of the project itself (for example, ripple effects of participants sharing their learning widely; participants continuing to use the skills and/or technologies they engaged with during the project; or behavioural change in participants because of their engagement with the project issues), including longitudinal follow-up to test these impacts could be beneficial.
    - Collecting demographic data, and other relevant information about participant backgrounds, could help identify who is and is not taking part in citizen science, and could help identify barriers to participation.

Recommendations for funding design

Through this evaluation project, we have identified challenges and successes of CSEG funding design, which inform the recommendations above. From these, recommendations for *future* funding design for citizen science also arise:

- **Support consolidation as well as innovation**
  Relationship management takes time, and this translates into a need for funding. This is important for the development of new relationships, seeking out new opportunities for collaboration, and reaching out to communities and groups beyond those already engaged with citizen science. However, maintaining existing relationships is also crucial, and requires time and effort, which can be facilitated through funding. Re-engaging with, and continually listening to, partners and participants can enable ongoing, sustainable citizen science to be built upon.

  This evaluative review was made possible by the documentation generated by the CSEG project researchers, with parity of information ensured by the parameters set by UKRI. This forms an important resource for shared learning. It has demonstrated the value in generating, archiving, and evaluating documentation on citizen science projects, and this could be facilitated through funding designed to support these endeavours.

  Citizen science projects depend on robust infrastructure for successful delivery, including appropriate tools and networks. For example, many of the CSEG projects used the Zooniverse platform (eg [11], [15], [20]). Furthermore, many projects depended upon networks they had built over the course of a broader research agenda. These tools and networks also require resourcing, and funding should be made available not only for projects but also for the infrastructure on which they depend.

  As discussed in the literature, and as seen in the way the CSEG programme integrated scientific/thematic topics into social, political and wider issues, advocacy is a key element of citizen science. However, advocacy for citizen science is also important. Communicating the quality of citizen science data and findings was identified as a challenge through this review, and funding could facilitate the communication of citizen science, through showcasing and demonstrating its value.

  A specific proposal that emerged during this evaluation process was for extensions of project time, but without corresponding increases to the grant value. As one interviewee noted: “The same money spread over a longer amount of time would allow you to do more in general”. This demonstrates that these projects were able to use a relatively small grant to accomplish a lot, and the key limiting factor they experienced was time rather than money.

- **Support co-production and co-learning**
  In cases where citizen science is understood to be participatory, and participants are involved in decision-making, time and flexibility can enable relationship development, and incorporate participants' needs and ideas. This

can require increased time and added resourcing for developing a proposal to enable:

- researchers to reach out to diverse participants, not just those who are easier to reach or with whom they already have pre-existing relationships;
- participants to have input into the design of the project before the proposal is submitted;
- researchers to work collaboratively with their networks, including communities they have established connections with, to co-produce proposals that reflect their wider networks' shared aims.

It can also require longer project delivery duration to enable:

- time for relationship-building, and/or the maintenance and strengthening of existing relationships;
- time for co-design, to incorporate both planned and spontaneous adaptability, responding to participant needs;
- the collection of participant feedback, including time for qualitative data analysis; and
- time to share learning, to inform wider citizen practice as well as to showcase the value of citizen science approaches.

- **Support researcher development**
  To enable researchers to develop and deepen their understanding of citizen science, to engage with the perspectives of other researchers and practitioners as well as research participants, and to facilitate career paths with ongoing citizen science research agendas, funders of research should consider offering:
  - pre-project and ongoing support/training, to enable researchers to develop the most innovative, creative and robust research proposals, and then deliver the best possible projects, training and support before and during project delivery would be highly valuable (especially in the case of ECRs);
  - in-built collaboration with other grantees, to share learning and best practice, but also to discuss and collaboratively overcome challenges, interaction between different project teams would be valuable; and
  - direct leads into further funding - to enable researchers to develop research agendas and relationships, opportunities designed into grants to develop projects further, and build upon exciting collaborations -

would facilitate long-term planning, career development, and network development.
Furthermore, these opportunities need to be sufficiently open to enable projects with different citizen science approaches to gain support, to maintain the diversity of the field. This includes opening funding avenues for both innovation and consolidation, inclusive to new and ongoing research agendas.

- **Support longitudinal follow up**
  To facilitate tests of longer-term impacts of citizen science projects, funders of research should consider offering follow-up funding:
    - For longitudinal evaluation, to enable researchers the time and resources needed to follow up with their participants (eg, tracking ongoing impacts on participants). Funding would need to be available and offered as part of the initial grant to promote planning and participant data-collection and retention.
    - For longitudinal impact research, to test for social impact, including changes in behaviour related to the initial study topic. This could be offered later, in addition to the original grant, as it can be planned for as a separate study (ie, where ongoing engagement from the same participants is not necessary).

Appendix A: References

Two different styles of referencing have been adopted within this report. Firstly, for published literature, an author-date reference system (APA 7th Edition) is used. Secondly, for the unpublished project reports submitted by the CSEG project teams to UKRI, a numerical referencing system (IEEE) is utilised. These different types of sources are listed separately in the reference list. This approach was taken to clearly differentiate between the published literature drawn on to contextualise our evaluative review, and the texts which formed the 'data' that we reviewed.

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Interviews

Case study 1: Stream Sleuths. National Trust: Stream Sleuths project. Interview March 1, 2022.

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Case study 4: U.K. Air Quality Archive. University of Bristol: Using the U.K. Air Quality Archive project. Interview March 15, 2022.

Case study 5: CERN OpenData. University of Oxford: Co-creation of CERN OpenData project. Interview March 25, 2022.

Appendix B: Methodology

Evaluation aims

This review focused on the learning that could be gained by analysing these diverse projects to collate the varied insights they could provide. It sought to shed light on both practical and conceptual issues around citizen science approaches, to both contribute to knowledge about citizen science as a research method, and to inform future research and funding design.

The key framing objectives were:

- understanding the successes/enablers and challenges of the citizen science projects, and the impact of the funding, at a programme level;
- understanding the successes/enablers and challenges of the citizen science projects and how these differ/align across different disciplines; research themes; and project approaches;
- understanding how the role of citizen science, as one method of involving the public in research, differs (or not) across projects in benefitting research and its relationship to wider society;
- informing how citizen science and participatory research is understood, delivered, valued, and funded in the future; and
- placing citizen science in the wider context of participatory methods for research and its stakeholders.

Based on the information available, our evaluation did not seek to make judgements about the quality of projects, nor to assess their outputs. Where successes were identified, these were drawn from the perspectives of the researchers describing them and were not deployed in any comparison between projects; rather our aim was sharing successes across projects to identify best practices and inform future work.

Method

The evaluation process followed an iterative approach, commencing with a review of the final reports and research outcomes from data collected through researchfish, followed by in-depth interviews with researchers from case study projects, and finally re-analysing the reports for further insight.

Our emerging findings and recommendations were reviewed and discussed with the researchers involved in CSEG projects in a roundtable session, and this informed the refinement of this report.

Thematic review

The 25 CSEG projects yielded a final report and additional questionnaire project summary data (ie, research outcomes data collected through researchfish) were analysed for themes that could shed light on our evaluation aims.

Firstly, a granular analysis of the reports was conducted by two researchers working independently, each undertaking an open coding process. The researchers then independently consolidated their open coding into concept codes.

At this stage, the researchers integrated their separate codes into overarching themes, through a holistic process of seeking meaning across their concept codes. In this process, value judgements were avoided, such that the researchers did not rank codes or qualify them as positive or negative but sought to derive themes in a way that reflected their presentation within the reports. As a result, three themes emerged, with sub-themes articulating detail within them.

The research outcomes data collected through researchfish was analysed in relation to these three themes, seeking any disconfirming data to challenge the themes, and integrating relevant information into the structure. The themes were found to adequately represent the questionnaire data in addition to the reports.

Development of project case studies

We sought diversity in our selection of five case studies from the total 25 available projects. This included:

- different participant types (local community members, school pupils, etc);
- different approaches to citizen science (ie, more data-oriented, and more participatory approaches);
- different types of organisation (ie, not only universities); and
- different subject areas

Furthermore, we sought case studies around different themes, and discussed successes and challenges. Projects that involved researchers and practitioners rather than citizen scientists as participants were not included in the case studies, as

the impacts upon citizen scientists were a key area of review. Not all contacted researchers were able to take part in the interviews, and therefore we iterated invitations until our target of five case studies was reached.

To obtain case study information, semi-structured online interviews were conducted with one or two research team members. These interviews were conducted online, lasting 45 minutes each. Interviews were recorded, with transcripts used for note-making, and thereafter deleted. Case study information is, by necessity, identifiable. However, individual researchers are not named within the case studies. Interviewees were given the opportunity to review the case study texts prior to their inclusion within this report. Interview responses pertaining to feedback on the CSEG funding design have been anonymised, ie, combined into an aggregated pool of information.

Interview topics included:

- citizen science as a method - what makes it different from other approaches;
- learning during the project - both for participants, and for researchers;
- sustainability of citizen science research approaches;
- successes and challenges of the project; and
- suitability of the grant, and other funding sources.

The full interview participant information sheet, and interview script, are below.

Seeking citizen scientists' voice

As part of this evaluation, engagement with the citizen scientists from the projects was planned. A survey was distributed via the CSEG researchers, seeking to gather participant experiences and invite people to take part in a focus group, with incentives offered for participation. However, as only a single participant completed the survey, our citizen scientist engagement was ultimately unsuccessful. Our lessons learnt from this process and recommendations for future research are documented above.

Limitations

This evaluation has limitations, which are vital in understanding these findings and in seeking to apply our learning more widely.

- **Findings from a researcher perspective:** The primary evidence used for this evaluative review comes from the CSEG researchers' perspective, through their final reports and interviews with project team members, and this is an important caveat to consider.

- **Scope of case study development:** We conducted five interviews with researchers, creating five case studies, as part of this evaluation project. However, a larger number of researchers were contacted than could take part in an interview. A significant barrier to researcher participation was strike action taking place during our review period in early 2022. We sought to keep the burden on researchers to a minimum by conducting 45-minute interviews. However, this limits the extent of data that could be collected for each case study, and those developed should be viewed as offering an insight into the key areas of interest targeted by the interview questions.

- **Format of report and data:** The final project reports, and research outcomes data collected through researchfish, submitted to UKRI by the project teams followed a specific format, and contained information grouped under common themes. On one hand, this enables a meaningful analysis of the reports taken together, with common themes emerging from the collective information. On the other hand, this means that some information that researchers may have felt to be relevant and important about their projects was not captured, as it did not fit the report or research outcomes data structure. An indication of this is seen in the fact that ripple effects (Sub-theme 3.3.c.) only emerged in the interview data and had not been identified in the reports or research outcomes data. Furthermore, some information - that may have been interesting to review - was not requested in the reports or research outcomes data, and interviews could not compensate for the omission; demographic data about participants was not included in project reporting, and to gain a sense of who was and was not represented with the study samples would require all (or most) of the studies to provide this information. It is also important to note that UKRI is a funder with considerable power, and this may have shaped the ways in which researchers chose to describe their projects (eg, some researchers may have felt a need to foreground successes over challenges to present a positive image to the funder). In our interviews and roundtable, we therefore emphasised the independent role of the Institute for Community Studies in conducting this review and created space for researchers to share their experiences without representatives of UKRI present, to minimise some of this possible pressure.

- **Participant voice**: The barriers in reaching out to the citizen scientists who took part in the CSEG projects have been discussed in the Citizen scientists' voice section of this report. As a result of these barriers, our evaluation did not include any direct input from the project participants. We have included reported citizen scientists' perspectives from the grant teams' final reports. However, findings pertaining to this information are interpreted through a researcher-oriented lens and are best understood as *researcher presentation of* citizen scientists' voice.

While some of our findings pertain to 'citizen science' as a research method, these findings are contextualised to the CSEG projects. The findings were derived from 25 projects that were all designed for the same funding call, and all selected for the same grant. They therefore represent an approach to citizen science that was shaped by the design of this grant (eg, the emphasis on relationship-building in the grant assessment criteria).

Interview participant information sheet

About this project

The Institute for Community Studies is conducting an evaluation of the UKRI-funded Citizen Science Exploration Grant (CSEG) projects, with the following aims:

- Understanding the successes/enablers and challenges of the citizen science projects, and how these differ/align across different disciplines; research themes; and project approaches; and the impact of the funding, at a programme level
- Understanding how the role of citizen science, as one method of involving the public in research, differs (or not) across projects in benefitting research and its relationship to wider society;
- Providing learning to inform how citizen science and participatory research is understood, delivered, valued, and funded in the future; and
- Placing citizen science in the wider context of participatory methods for research and its stakeholders.

As a result of this evaluation, we will produce a report for UKRI with recommendations for facilitating best practice in future citizen science research.

Why have you been invited to participate?

We reviewed the final reports from the CSEG projects, and selected case studies from projects that used diverse methods across different subject areas, from which we could gain a variety of perspectives. You have been invited to take part in an interview as your project was selected as a promising case study, to help us learn about citizen science. We are not assessing the successes of the projects, but rather seeking learning opportunities across the projects to further this field and aiming to identify what is required to better support this approach to research.

As a result of this evaluation research, we will be producing a report for UKRI, which will feature case studies on a small number of the CSEG projects. The report will be publicly available and we will share our findings widely, including with those interested in citizen science as a research approach.

Interview format

The interview will be held online, via video conferencing platform. The interviewer will be Dr Helena Hollis, Senior Researcher at the Institute for Community Studies. The interview will take 45 minutes.

Interview topics

The interview will cover the following topics:

- Citizen science as a method - what makes it different from other research approaches
- Learning during the project - both for participants, and for researchers
- Sustainability of citizen science research approaches
- Successes and challenges of your project
- Suitability of the grant, and other funding sources

Your data

Recording and transcription

The interview will be audio-recorded and transcribed. Transcripts will be used for thematic analysis to inform our findings and recommendations. Pseudonymised quotations may be used in our outputs, but the recordings and transcripts themselves will not be shared outside of the Institute for Community Studies research team.

Please be aware that while we will pseudonymise the transcripts and any quotations used will not be attributed (ie, we will not name you), the nature of our case study focus requires us to include the details of your research project and as such your data will be identifiable.

Recordings and transcripts will be deleted no later than May 2022.

Confidentiality

Prior to their use, the case study descriptions derived from the interviews will be shared with interviewees and you will have the opportunity to redact or refine any information you wish.

Where topics are discussed for which you wish to be fully anonymous (for example discussing issues around funding), you can notify us and we will agree with you to only share your views without any identifying information. For example, in presenting any critique of the CSEG grant structure, we can combine input from across all case studies without any detail of individual projects.

Consent

You do not have to take part in this interview; your participation is entirely voluntary. You may withdraw from the interview at any time, without giving any reason.

Prior to the interview, you can cancel at any time. During the interview, you may simply end the online video call to withdraw from the interview. Any data collected will be deleted if you withdraw your participation. You may also ask us to delete your data after the interview at any time, and we will do so.

We will obtain your consent prior to commencing the interview by asking you to confirm with a yes/no answer:

- You have read and understood this information sheet

-You consent to taking part as described by this information sheet

-You will have the opportunity to ask the interviewer any questions prior to the start of the interview.

Interview script

The Institute for Community Studies is conducting an evaluation review of the Citizen Science Exploration Grant projects, looking at the role of citizen science as one method of involving the public in research, and seeking to collate learning to inform how citizen science and participatory research is understood, delivered, valued, and funded in the future.

As part of this review, the Institute is conducting interviews with researchers of some selected Citizen Science Exploration Grant projects they have identified as of special interest in understanding citizen science approaches.

The interview will cover the following questions, though with flexibility for you to move the conversation beyond these specific questions, or to focus on some more than others.

Citizen science

1. Could you give a definition of what 'citizen science' means, in your own words?
2. During this project, do you think that your understanding of 'citizen science' changed or shifted at all?
3. What do you think citizen science methods can uniquely contribute, in contrast with other approaches?
4. Could you summarise some of the key elements of best practice for citizen science? What should a researcher who wants to design an excellent citizen science project be focused on?

Learning

1. To what extent was participant learning an aim of your project?
    a. What kinds of things did you want your participants to learn?
    b. How did you intend for the participants to learn this?
    c. What is your perception of what the participants learned, and were there any unplanned learnings?
2. Was researcher learning also something that you designed into your project?
    a. What do you think you and your team learned from the project?
3. Do you think there is anything about "'citizen science'" as a method that has some unique learning opportunities for researchers?

Sustainability

We are interested in how citizen science projects can have a legacy beyond the project end-date, for example in outcomes, or in participants' ongoing engagement.

1. Did you have any longer-term aims for your project, beyond the timeframe of what was proposed?
2. Do you think there is anything about the nature of 'citizen science' as a method that can make it more or less sustainable - having more longer-term impact or enduring effects - than other approaches?

Successes and challenges

1. What were the main challenges you encountered in your project?
    a. How did you navigate/overcome these?
2. With the benefit of hindsight, is there anything you would do differently next time to mitigate these challenges?
3. What do you see as the greatest successes of your project?
    a. How does this compare to your hopes/aspirations at the start of the project?
    b. Were the successes anticipated, or did they play out in a different way than you intended/ imagined?

The Citizen Science Exploration Grant and other funding

1. How do you feel the grant worked for your project?
2. Were there any limitations placed upon the project by the way the grant was set up?
3. If you could redesign the grant, what would you change about it?
4. Did you seek any additional funding beyond the CSEG grant to conduct the project? Why/why not?
5. Did you apply for funding to extend the project, or run any kind of follow up research?
    a. If yes, how did that go? Why do you think you were successful /unsuccessful in the application?
6. Is there anything else you would like to tell us about your experience of the Citizen Science Exploration Grant?

Final thoughts

1. Based on what you've learnt and found during CSEG, if you were advising other projects or teams similar to yours, what key advice would you have for them?

Appendix C: Breakdown of grants

Project departments

Figure 1 shows a breakdown of the number of CSEG projects by department.

Figure 1: Breakdown of CSEG projects by affiliated department.

Department	No. of CSEG projects
Environmental sciences	5
Mathematics and physics	5
Geography	4
Life and health sciences	3
Education	2
Engineering	2
Politics and international relations	2
Psychology	1
Chemistry	1

NB. Departments have been grouped under common headings, to reconcile different naming and classification conventions, for example ‘School of Mathematics and Physics’, ‘Astrophysics Research Institute’ and ‘Physics’ have been grouped together under *Mathematics and physics*. Where no department was present (eg, The National Trust) the closest thematic department to the project study area was used.

Award title	Institution	Department
Using the UK air quality archive in primary schools	University of Bristol	Chemistry
Citizen inquiry: barriers, challenges and enablers for public engagement	University of Hull	Education
EDUcating Citizens and organisations in Citizen Science methodologies (EduCS)	Open University	Education
Geospatial design of energy systems for Africa: citizen science	University of Oxford	Engineering
Identifying, developing and embedding citizen science techniques in action research to evaluate locally led solutions for water quality monitoring	University of Warwick	Engineering
‘My house, my rules:’ co-designing residential air pollution research	King's College London	Environmental sciences
Assessing the value and challenges of using citizen-science to understand plastic pollution in the marine environment	University of Exeter	Environmental sciences
Exploring new placed based technological opportunities for community science with the Marine Biological Association and Time and Tide Bell	Marine Biological Association	Environmental sciences
Citizens' Data for Air Pollution (CitiDAir)	Institute of Occupational Medicine (IOM)	Environmental sciences
Stream sleuths: using fish eDNA to determine shared catchment actions	National Trust	Environmental sciences

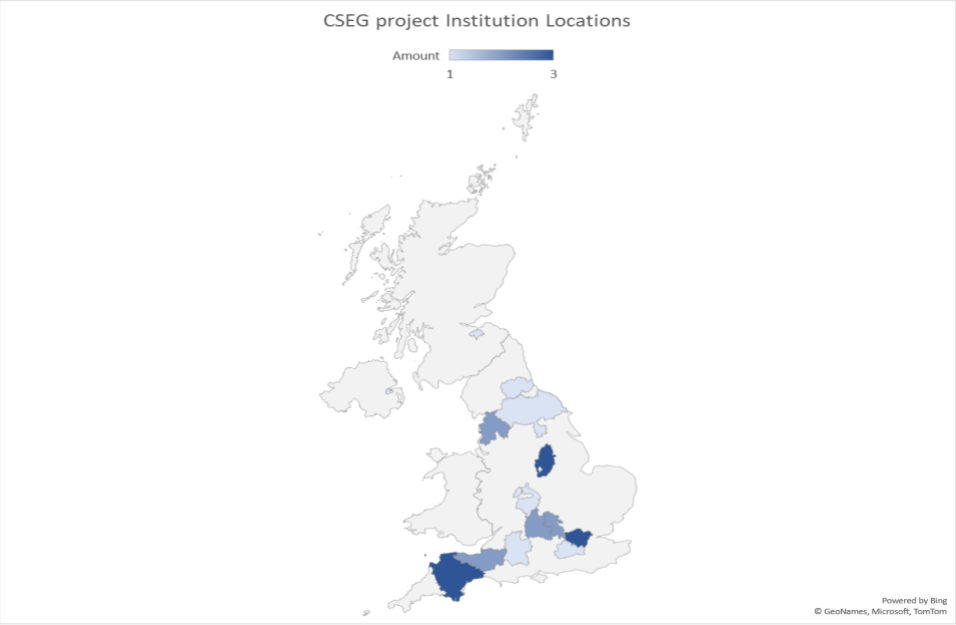
Award title	Institution	Department
Identifying synergies between citizen science and Long-Term Socio-Ecological Research (LTSER) in the Cairngorms National Park	University College London	Geography
SoilSCAN: Soils, Science and Community ActioN	University of Plymouth	Geography
GlacierMap: mapping glacier change in the Peruvian Andes	University of Plymouth	Geography
Citizens4EO	University of Nottingham	Geography
Exploring community responses to health-related community displays	Open University	Life and health sciences
Crowd-sourcing SuperYeast	Aston University	Life and health sciences
Swat or not? Identifying insects in Virtual Reality	University of Nottingham	Life and health sciences
Developing opportunities for in-depth citizen science using robotic telescopes	Liverpool John Moores University	Mathematics and physics
Co-creation of CERN OpenData projects with UK school students - pilot study	University of Oxford	Mathematics and physics
First encounters with quantum computing: can games teach quantum reasoning?	Durham University	Mathematics and physics
Innovative digital citizen science: active learning for disaster relief	Lancaster University	Mathematics and physics
Exploring citizen science use cases with the Lasair transient alert broker	Queen's University Belfast	Mathematics and physics

Award title	Institution	Department
Using citizen science to promote transparency in British election campaigns	University of Nottingham	Politics and international relations
A citizen assembly pilot on energy transition in Lebanon	University College London	Politics and international relations
Marine litter citizen science research agenda - an expert perspective on advancing the citizen and the science in citizen science	University of Surrey	Psychology

Institutions by county

CSEG grantees were primarily situated within universities. However, some projects were affiliated to charities: Institute of Occupational Medicine (IOM) [13]; National Trust [9]; as well as a learned society: The Marine Biological Association [14]. The geographic distribution of GSEG project hosting institutions across the UK can be seen in Figure 2.

Figure 2: Breakdown of CSEG projects by institutions and their locations



Most institutions had one CSEG project. However, the University of Nottingham had three CSEG projects; Oxford University, UCL, University of Plymouth, and the Open University each hosted two CSEG projects.

County	Institution
Buckinghamshire	Open University
Country Durham	Durham University
County Antrim	Queen's University Belfast
Devon	Marine Biological Association
Devon	University of Plymouth
Lancashire	Lancaster University

County	Institution
Lancashire	Liverpool John Moores University
London	King's College London
London	University College London
Midlothian	Institute of Occupational Medicine (IOM)
Nottinghamshire	University of Nottingham
Oxfordshire	University of Oxford
Somerset	University of Bristol
Somerset	University of Exeter
Surrey	University of Surrey
Warwickshire	University of Warwick
West Midlands	Aston University
Wiltshire	National Trust
Yorkshire	University of Hull