CITIZEN SCIENCE:
THEORY AND PRACTICE

Beyond Science: Exploring the Value of Co-created Citizen Science for Diverse Community Groups

CASE STUDIES

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ABSTRACT

Addressing global environmental challenges and making progress towards the United Nations sustainable development goals (SGDs) requires transformative change in various aspects of coupled human-environment systems. Public participation and collective action at local levels through improved ocean literacy is an important part of achieving global targets. However, inequalities in who has access to opportunities to engage with science and connect with ocean environments persist. Here we explore the value of co-created citizen science with four diverse community groups using the value-creation framework. We utilize participatory evaluation processes with focused group discussions (n = 17) and surveys (n = 58) embedded throughout the research process. We evidence how co-created citizen science can facilitate transformative experiences leading to pro-environmental behaviors, community empowerment, shifts in perceptions, and community building. Our findings highlight the value of such approaches to elicit change and their potential to influence policy through behavioral change.

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INTRODUCTION

Our oceans currently face a multitude of complex socio-ecological challenges with human impacts considered significant and indisputable (Côté et al. 2016). The pressures of overfishing, habitat loss, pollution, and climate change are intensifying (Geldmann et al. 2014; Maxwell et al. 2016), leading to unprecedented change (Beaugrand et al. 2019) with local to global implications for human well-being (Steffen et al. 2015). In response, the United Nations has proclaimed the Ocean Decade for Sustainable Development (2021–2030) to promote ocean science and support global efforts to overcome socio-economic and environmental issues linked to marine ecosystems.

Solutions to these global problems require the collation of sound scientific evidence that embraces diverse knowledge systems while also enhancing societal empowerment and ownership. Public participation and collective action by local stakeholders (e.g., individuals, community groups, local authorities) are therefore key to achieving inclusive sustainable development across all major global agendas (Moallemi et al. 2020). However, the ocean decade goals and other interlinked development targets (e.g., Sustainable Development Goals [SDGs] 10, 13, 14, 16) are still primarily understood as top-down frameworks, driven by governmental action. Formal governance through international institutions, regional organizations, or governments should be coupled with local, bottom-up initiatives to enable more transformative and responsive policies that consider diverse social, environmental, and economic contexts (Bulkeley and Castán Broto 2013; Fuenfschilling et al. 2019). This will require more effective engagement processes that recognize and support the diversity, identities, and abilities of local actors and can in turn facilitate the mobilization of communities to participate in these processes.

A well-recognized enabler of transformative change towards sustainable development pathways and greater participation in environmental decision-making is improved ocean literacy (Ferreira et al. 2021). Raising public awareness and knowledge of environmental issues and enhancing community connections to the ocean can foster pro-environmental attitudes and behaviors (Duarte et al. 2020), and empower communities to take a meaningful stake in tackling environmental challenges. However, structural inequality and socio-economic disparity threaten opportunities for people to engage with science and directly connect with ocean environments (Dawson 2018; Kelly et al. 2022). Expanding opportunities and breaking down barriers for people from diverse and marginalized backgrounds to participate in scientific research is recognized as a key challenge, and major disparities persist (Jimenez et al. 2019). Shaped by social forces such as race, gender, class, access to power, and language (Lewenstein 2019), scientific research remains inaccessible to large proportions of society (Dawson 2014, 2018). This inequity raises important questions around the relevance and representativeness of science, including whose voices are being heard and whose are silenced.

Citizen science is increasingly recognized as a pathway for enhancing stakeholder engagement in scientific research and facilitating knowledge exchange between academic and non-academic groups (Agnew et al. 2022). Defined as the active involvement of members of the public in scientific research, citizen science can be categorized into three practices: contributory, collaborative, or co-created (Bonney et al. 2009). In co-created models, citizens and scientists work together through all stages of the research process (Gunnell et al. 2021) with individuals, communities, and social groups recognized as co-producers of knowledge (Kythreotis et al. 2019). Primarily associated with scenarios in which citizens have a specific concern or question they would like to investigate, co-created citizen science can enable scientific evidence on environmental issues to become more salient and can also lead to greater social impact (Shirk et al. 2012; Stevens et al. 2014). Co-created initiatives also provide opportunities to integrate diverse knowledge and value systems and are increasingly recognized as essential for achieving significant progress towards achieving the SDGs (Ansell et al. 2022).

However, the evaluation of such initiatives often fails to acknowledge the complexities of the learning process and experience, leaving critical gaps in understanding what engagement means for participants (Phillips et al. 2019). Typically, engagement in citizen science has been defined through quantitative output measures such as the number of participants, the amount of data collected, and the rates of submission (Phillips et al. 2012). Very few studies have qualitatively evaluated the impact of citizen science engagement, particularly from the perspective of participants (Phillips et al. 2019).

With this paper, we aim to evidence how citizen science projects co-created with communities have important and multifaceted benefits for those participating in co-creation. Using four case studies with diverse community groups we explore participant experiences as they work collaboratively to co-create environmental citizen science projects. Framing for our data analysis was informed by the value creation framework (VCF)—a theoretically driven framework to trace the value created by learning in communities and networks (Wenger et al. 2011). Participants involved in the learning space were co-researchers engaged in a collaborative process of investigating, sharing, and reflecting on their practice.

CONTEXTUAL SETTING

The following sections provide contextual information about each of the citizen science projects and the co-creation research processes that were undertaken. We use the term co-researchers for the community members with whom we co-created the citizen science projects and the term academic researchers to describe ourselves.

CITIZEN SCIENCE PROJECTS

We (academic researchers) co-created environmental citizen science projects (Table 1) with diverse community groups in northeast England (Table 2). Projects were developed as part of the Engaging Environments project (https://engagingenvironments.org/), a UK-wide platform to build a national community of environmental scientists and diverse communities. Projects included co-researchers in key decision-making processes throughout all the research phases, to co-create projects that addressed local concerns and/ or interests. In each of the projects, we used our expertise to provide technical guidance and training to support project development and develop capacity among co-researchers to ensure meaningful outcomes and activities. We also facilitated group discussions.

The art-science collaborative brought together women from Bangladeshi heritage and combined environmental awareness with participatory arts practice. Ten creative workshops were used to share stories and perspectives and facilitate personal connections to environmental challenges on both a local and international scale. Artwork created from recycled materials and plastics formed a platform for the group to express their concerns around climate change and plastic pollution and raise awareness for the marine environment in the wider community with artwork displayed at a public exhibition. In the workshops, academic researchers first set the scene by delivering thematic environmental talks (themes chosen by co-researchers) and facilitating discussion as it evolved throughout the workshop.

In the Intertidal Biodiversity project, young climate activists and residents from a coastal town in northeast England co-designed an environmental citizen science project with academic researchers to document local

PROJECT	KEY PROJECT GOALS						
	COLLECT ENVIRON-MENTAL DATA SETS	EDUCATION AND AWARENESS	CONNECT TO LOCAL MARINE ENVIRONMENT	DEVELOP RESEARCH SKILLS	ENGAGE WITH SCIENCE AND RESEARCH	INCREASE ENVIRON-MENTAL STEWARDSHIP	BREAKDOWN BARRIERS TO PARTICIPATION
Art-science collaborative		X	X		X	X	X
Intertidal biodiversity	X	X	X	X	X		
Marine ecological communities		X	X		X		X
Plastic pollution	X	X	X	X	X	X	

Table 1 Summary of co-created project goals.

PROJECT	DURATION (MONTHS)	CO-RESEARCHERS	DEMOGRAPHICS
Art-science collaborative	8	15	Age: 35–44 (11%), 45–54 (55%), 55–64 (34%) Ethnicity: Asian (100%) Gender: female (100%)
Intertidal biodiversity	13	9	Age: <18 (82%); 35–44 (18%) Ethnicity: White (100%) Gender: female (73%); male (27%)
Marine ecological communities	11	10	Age: 25–34 (25%); 35–44 (50%); 55–64 (25%). Ethnicity: White (100%) Gender: male (20%); trans-male (20%); female (20%); trans-female (20%); other (20%).
Plastic pollution	11	28	Age: 18–24 (4%) 25–34 (35%); 35–44 (46%); 45– 54 (11%); 55–64 (3%). Ethnicity: Asian (11%); Black-African (7%); Mixed (4%), White (78%) Gender: female (100%)

Table 2 Co-researcher demographics.

intertidal species and contribute to long-term monitoring efforts in the region. Initial participatory workshops explored shared concerns relating to climate change and the impact this was having both locally and globally. Co-researchers undertook training (led by academic researchers) between March and June 2022 to develop local capacity to conduct intertidal surveys that covered rocky shore ecology, species identification, and intertidal monitoring methods. Data were then collected following a standardized protocol to record key species abundance.

In the Marine Ecological Communities project, co-researchers were adults from an LGBTQ+ community group. The project centered around an iterative process of engagement to jointly explore perspectives around science and the environment, and co-design inclusive approaches to science communication. The project consisted of a series of four workshops in which diverse participatory methods were used to facilitate knowledge co-production. Workshops included thematic discussions covering a broad range of environmental topics (e.g., climate change, plastic pollution, biodiversity loss) and practical activities including small scale citizen science projects to investigate topics of interest (hermit crab behavior) and concern (microplastics). Academic researchers organized practical activities and facilitated thematic discussions.

In the plastic pollution project, women—mainly Eastern European—and their families from an international community group co-designed a citizen science project to document and tackle marine litter and plastic pollution in the city of Sunderland. The project consisted of a series of engagement events to raise awareness of and connect the group to their local coastline (led by academic researchers), followed by four participatory workshops and two beach clean-up events. During the participatory workshops, knowledge was co-created using focused group discussion, storytelling, and participatory mapping to build a comprehensive understanding of issues by drawing on lived experience and local knowledge. Participatory mapping identified litter hotspots, and surveys were conducted to document the amount, type, and potential sources of plastic pollution between May and October 2022.

PROJECT CO-DESIGN

Each project followed a four-phase approach consisting of multiple, iterative phases of 1) relationship building, education, and awareness; 2) co-design; 3) co-production; and 4) action, with evaluation embedded throughout the co-creation process (Figure 1). Academic researchers developed the model and outlined each research stage at the beginning of the project. However, this was not considered a linear process as studies progressed iteratively, with co-researchers involved in decisions and project design at all stages.

The education and awareness phase (phase 1) can be broadly broken down into two key components 1) building relationships with community partners and 2) education and awareness. In three of the projects (art-science collaborative, plastic pollution, marine ecological communities), academic researchers established contact with community intermediaries using targeted invitations. This has been shown to be an effective way to reach underrepresented groups and ensure project legitimacy (Stevens et al. 2014). Participants from the intertidal biodiversity project contacted academic researchers directly to explore the potential of collaborating on a local environmental project. Following collaborative discussions and planning between researchers and group intermediaries', ideas were pitched to community groups to assess interest and community buy-in. Academic researchers then attended existing events (e.g., clean-ups, social events) to meet group members and build relationships. This stage was also used to develop a tailored education and awareness program to ensure an inclusive and accessible co-production environment. Academic researchers led awareness programs, however co-researchers provided input on the types of activities/topics they wanted covered.

The co-design phase (phase 2) primarily consisted of participatory workshops (facilitated by academic researchers) to identify environmental concerns or key topics of interest, formulate research questions, and design projects. Brainstorming activities were followed by collective decision making via visualization, dot voting, and focused group

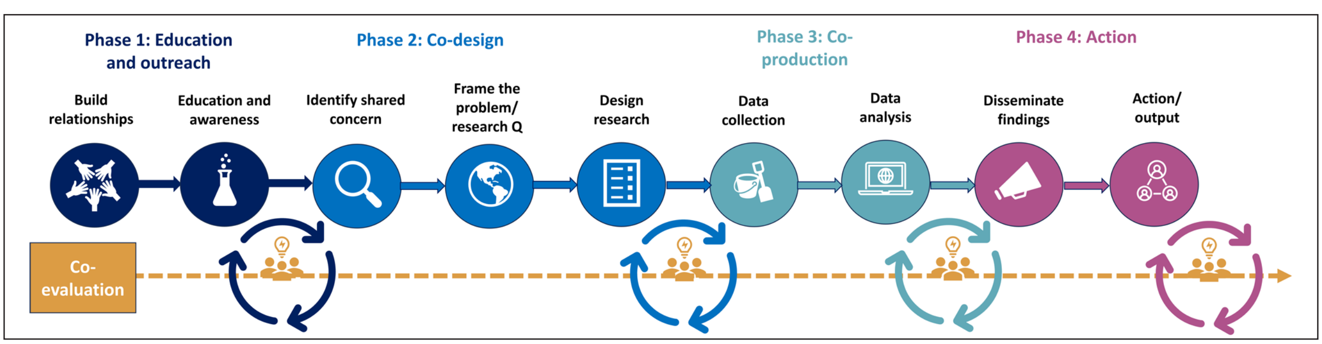

Figure 1 Key phases of the co-creation research process employed by each project group.

discussion to prioritize research themes and questions. This phase also included project-specific trainings led by academic researchers to build local capacity and pilot project design.

The co-production phase (phase 3) focused on collaborative research tasks. In the case studies discussed here, phase 3 involved data collection and analysis (intertidal biodiversity, plastic pollution, marine ecological communities projects), knowledge co-creation (undertaken across all projects), and participatory artwork (art-science collaborative). Co-researchers led the co-production phase, with academic researchers present to facilitate discussions and provide any technical guidance (e.g., species identification).

In phase 4, projects used participatory workshops to plan and co-design actions informed by data collected in phase 3 and ongoing evaluation. A key goal across each of the projects was to raise wider awareness of project findings; key examples include public events (e.g., art exhibition), reports on social media, and lobbying for local change.

Co-evaluation was an ongoing aspect of the project, embedded within each of the research phases (Figure 1). Evaluation was participatory with co-researchers actively collaborating in all evaluation stages (Kieslinger et al. 2022). At the end of each workshop or activity, space and time was set aside to reflect on the day, activities, and the research process, enabling an iterative process that informed projects as they progressed. Additional evaluation activities included focus group discussion, interviews, and retrospective surveys.

METHODS—DATA COLLECTION

This study employed a mixed-methods approach, using qualitative and quantitative data. We conducted 17 in-person focus group discussions with co-researchers (Appendix A: Table A1), each lasting between 25 and 80 minutes. To structure focus group discussions, we used Wenger et al.'s (2011) value-creation framework (VCF) to evaluate the experiences of co-researchers involved in the co-creation of environmental citizen science projects (Table 3). The VCF has five value cycles that are outlined below and described in relation to our co-created citizen science projects: 1) immediate value refers to co-researchers' experience of the activities undertaken throughout the co-creation process, for example, co-researchers' experience of conducting shore surveys; 2) potential value concerns the knowledge, skills, resources, and networks gained through participation in the project; 3) applied value is generated when co-researchers apply their learning or knowledge, and in this study, includes both within (i.e., data collection) and outside of the project (change in behavior); 4) realized value is evident in project outcomes and how this benefited co-researchers and the wider community, for example, new skills and knowledge led to the collection of data that identified local litter hotspots; 5) transformative value is achieved for a co-researcher when they have gained, through participation and application, new insights that transformed initial perspectives, values, or behaviors. The open-ended nature of focus group discussions allowed questions to be tailored to emerging themes and permitted further enquiry; however, care was taken to not lead or influence discussion. All focus group discussions were recorded for transcription.

Surveys were also administered to all co-researchers at the end of each project, either in person or online, depending on group preferences. A total of 58 surveys were completed. Surveys included both open-ended and 5-point Likert-scale questions (Appendix B) including retrospective post-then-pre design questions to capture self-reported changes in knowledge, skills, attitudes, and behaviors. This approach was chosen as it helps control for response shift bias (Colosi and Dunifon 2006) and avoids formal questions

VALUE CREATION CYCLE	
Immediate value: What happened and what was your experience of it?	• Overall, how was your experience participating in the Engaging Environments project? • Have you found the activities interesting? • What has been your favorite aspect about being involved in the project?
Potential value: What did you gain from participating?	• For you personally, what were some of the greatest benefits of participation? • Did you gain any new knowledge or skills?
Applied value: What difference has it made?	• Have you applied the skills and knowledge developed? If so how? • Has participation influenced your behavior or feelings towards the environment?
Realized value: What value was created for co-researchers/ wider community/ environment?	• Can you describe a key outcome from the project (this could be data collected, resources developed, artwork etc.). • Has participation influenced your ability to change your environment or community?
Transformative value: What perceptual shifts happened? At the individual or wider community level.	• Has participation changed your perception of science and research? • Has participation influenced your community?

Table 3 Conceptual framework: Key guiding questions for focus group discussions.

about knowledge at the beginning of projects before relationships have been established.

DATA ANALYSIS

Mean scores were calculated from retrospective surveys with significant differences based on paired t-tests and statistical power for comparing means given the standard deviation. Dependent variables (perceived outcomes) were treated as continuous variables, assigning the values 1–5 to Likert-scale response categories (e.g., responses coded as 1 for strongly disagree to 5 for strongly agree). Statistical analyses were conducted in RStudio (R version 3.6.1; R Core Team 2019). The focus group discussions were transcribed verbatim by the primary researcher (DR). We then undertook a thematic analysis using an iterative, inductive approach, to identify common themes across co-researcher experiences. The focus was to understand what was emerging as important to co-researchers in terms of what they gained, and how participation in the project had impacted them. Data was grouped into primary overarching themes and value creation cycles.

RESULTS

An overall snapshot of our data is provided in Figure 2. Findings are organized into five sections representing the five cycles of the VCF, although some overlaps are evident (Figure 2; Tables 4–8). We also color code value/ experiences described by co-researchers based on the key themes that emerged from qualitative analysis. Selected quotes were chosen as examples of the main findings and highlight the different types of value perceived by co-researchers and how these are interlinked across cycles.

IMMEDIATE VALUE

Across each project, all participants considered project activities interesting and 89% felt comfortable sharing and discussing ideas. An array of feelings and emotions was evident among the four projects; however, participants consistently cited feelings of surprise—linked to encountering new species or learning something new; excitement about their participation in the project and the new opportunities this presented; and enjoyment at spending time outdoors (Table 4). Participants also highlighted the value of being

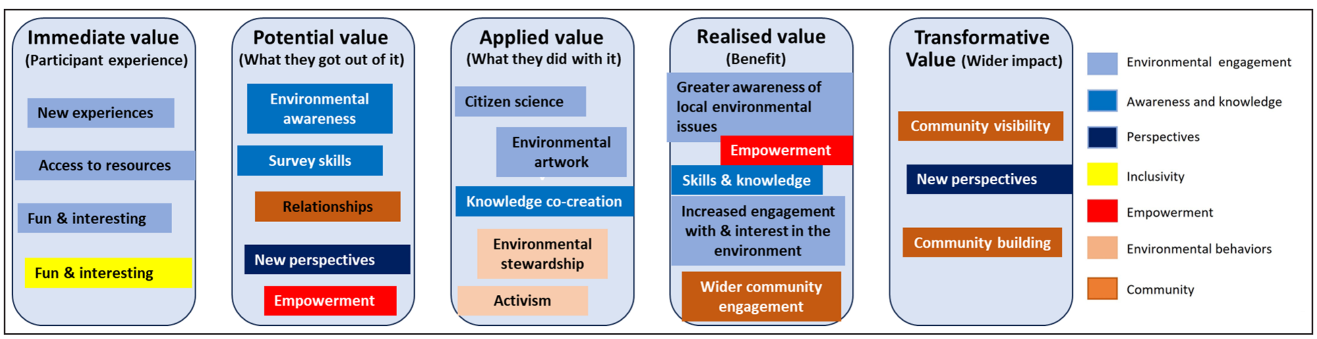

Figure 2 Value creation across cycles. Findings are color coded based on emerging themes.

New and practical experiences – Immediate value
"We have engaged with everything that is going on in the environment and have been very practical and hands-on"
"It has opened up a new world for us"
"Seeing the vulnerable people we support have new experiences, get into nature for the first time in years and explore aspects of the coastal community that might otherwise have been inaccessible to them"
Resources – Immediate value
"I don't think we would have otherwise had the opportunity to use that technology and be around people who work with this everyday who can show us what we are actually looking at" "There is a very large gap between looking at pictures of micro-organisms and actually getting a microscope to look. It really brings how real the whole situation is"
"They would have absolutely no access, no way they will ever have access to that kind of knowledge or resource unless we create that environment and those pathways for them to not just engage but also have that journey"
Positive experiences – Immediate value
"I have loved being out on the shore and exploring the rockpools"
"This is something I would never think to do, but I have really enjoyed all of the activities"
"Feeling engaged in the project design and data collection process in a fun environment"

(Contd.)

Voice and inclusivity – Immediate value
"The workshops have been fantastic to explore project opportunities together"
"Lots of opportunities to articulate, share and discuss ideas"
"Everyone has been able to share and it has been great to hear other perspectives"
"There are barriers to accessing the coastline. One of them is confidence. But being able to come in a group like this which is supportive and come somewhere which we know is going to be a supportive environment to take part in something that we wouldn't usually do really important"
"We don't have a voice in the climate crisis. People do not listen. It is really important for us to be involved in this and to collect data locally"
"Sharing knowledge and the activity with a group of people different ages and with different ways of looking and learning"
Well-being – Immediate value
"Spending time outdoors with friends in a fun environment is something I look forward too"
"We don't often have the opportunity to visit the coast, its been a fantastic experience"
"I struggle with my mental health but feeling involved and being able to focus on something new has helped"

Table 4 Key themes and supporting data within the cycle of immediate value.

Environmental awareness – Potential value
"I can't believe how everything is so interlinked and I feel I now know so much more about issues that our environment faces and want to keep learning more"
"Coming here we know so much more about the environment than we did"
"I have a much greater appreciation for all the species we have on our local shore. I never really paid attention to just how many different species there are here, now I know where to look and what to look out for I can't stop myself"
Skills – Potential and applied value
"Getting out on to the shore and collecting data has really helped me apply my species identification skills"
"I have learnt more about the local marine environment, data collection methods, data analysis and important things to consider like potential errors and biases"
"Learning about computer programs (R Studio) and statistical tests"
Empowerment – Potential and realised value
"I think the awareness we now have makes it easier to discuss science and help others understand too"
"I don't know if I can contribute to all issues, but I think we can be part of finding solutions"
"If you told me one year ago I could collect data to help understand the environment I would never have believed it"
"If someone talks about the environment I now know I can participate in the conversation, I have that confidence"

Table 5 Key themes and supporting data within the cycle of potential value.

able to share and discuss ideas in a supportive environment (Table 4).

POTENTIAL VALUE

Most co-researchers agreed that participation had increased their knowledge of the environment (45% agreed; 55% strongly agreed) and interest in science (18% agreed; 55% strongly agreed). Those who did not perceive a change in their interest in science (17%) indicated that they already had a strong interest in science and/or research. All co-researchers also agreed (42% agreed; 58% strongly agreed) that they were now more likely to engage in future scientific activities.

Open-ended responses suggest that the hands-on and practical opportunities provided facilitated the observed increase in knowledge while also sparking interest in scientific processes (Table 5). Co-researchers noted an increase in their own understanding of science, the scientific process, and/or citizen science due to their participation (Table 5).

APPLIED VALUE

When examining open-ended responses, the most frequently cited behavioral change was increased engagement in environmental discussion. Co-researchers suggested that increased awareness or understanding of the environment and environmental issues led to a sense of empowerment and confidence to share project learnings (Table 6), with many stating that they now discuss environmental issues with friends and family and

Environment stewardship and activism – Applied value
"I have started thinking about the plastic I use and how I can reduce this"
"I feel more aware, and this has come back into my own house we share what we have learnt"
"I was really saddened and shocked to learn more about the impacts that humans are having on our environment and bringing that into a local context helped me identify areas that I can work on to be more environmental conscious".
"It is a gradual process, but we are now raising awareness within the wider community"
Practical outputs – Applied and realized value
"I feel like it's so important that we have the opportunity to be involved in this and collect data that could help our environment"
"I was shocked at just how much litter we removed, I hope people will now listen and do more to help with the issue"
"The exhibition has reached a lot of people and has really helped raise awareness of our community"

Table 6 Key themes and supporting data within the cycle of applied value. Note overlap with realized value for practical outputs.

PROJECT AIM	QUESTION	PRE (MEAN SCORE)	POST (MEAN SCORE)	p VALUE
Interest and engagement	I think science is fun	2.4	4.3	<0.001
	I enjoy talking about the environment and science	2.0	4.9	<0.001
	I would like to learn about the marine environment	4.0	4.4	0.186
	I would like to participate in local environmental projects	2.3	4.1	<0.001
	I am interested in science and environmental research	2.6	4.8	<0.001
Empowered communities	I can participate in science and environmental research	1.9	3.9	<0.001
	I can collect data to better understand environmental issues	1.8	3.9	<0.001
	I can talk to people about threats impacting our environment	1.6	4.9	<0.001

Table 7 Changes in co-researchers' interest in and engagement with environmental science and research (n = 57).
Note: Response options were 1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5 strongly agree.

have become more active in raising wider awareness. Others described undergoing change in the way they engaged with environmental issues. For many, this focused on lifestyle changes (e.g., reducing plastic and energy use, increasing recycling, and buying local produce).

REALIZED VALUE

In the context of the four case studies discussed in this study, realized value was two-fold, relating to both intended and unexpected project outcomes. Intended outcomes considered the achievement of project aims developed by co-researchers at the beginning of each project (Table 1), such as collection of environmental data that addressed local concerns or wider community engagement through art (see Table 6). Unexpected outcomes relates to measurable change in co-researcher perceptions relating to their interest in, and ability to contribute to, science and environmental research. Co-researchers' perceptions of science and their interest in engaging with environmental projects significantly increased following engagement with their respective projects (Table 7). Similarly, co-researchers' responses regarding their ability to participate in environmental research increased significantly (Table 7). Average scores relating to interest in learning about the environment also increased, although not significantly.

TRANSFORMATIVE VALUE

Most co-researchers described some form of transformation in their perspectives, which were coded into two major themes: science-related and community-related. Most commonly, co-researchers described a shift in how they view scientists and the scientific process, noting that they now consider science to be much more accessible than previously envisaged (Table 8). For some, participation has changed long-standing ideas around "who science is for" and "who can participate in science" with hands-on experiences breaking down barriers. Others noted that participation has enriched their understanding of research practice (Table 8).

NEW PERSPECTIVES – TRANSFORMATIVE VALUE	
BEFORE	**AFTER**
"Science is only for people in professional jobs – people that are educated"	"The project has shown me that yes I can contribute, I can collect data to help understand and protect our environment"
"Science is not for me"	"It's opened up a new world for me, now all I watch is David Attenborough, its completely changed how I think of science"
"I have never heard of environmental science"	"I have learnt so much, I now have a greater appreciation of how science is done and why"
"We think climate change is a rumour, scientists have been talking about this for years"	"We see what the scientists said is true – we see this in Bangladesh"
"Science is very technical – on TV it is all lab focused – I don't think I can be part of that"	"It has been much more accessible than I envisaged science being, we have engaged in a very practical and hands-on way"
WIDER COMMUNITY ENGAGEMENT AND BELONGING – TRANSFORMATIVE VALUE	
"It has helped us feel part of a community, and more part of the community that is around us"	
"With us venturing out it has made people more aware that we are here and increased awareness of what we need to be safe"	
"We are breaking down perceptions and showing just what we can do"	

Table 8 Key themes and supporting data within the cycle of transformative value.

For each community group, the social and collaborative dimension of their projects were particularly important. Engagement with the environment, environmental issues, and the academic community fostered a sense of belonging and feelings of connection to the wider community (Table 8). Co-researchers also described the way in which project activities had helped increase community visibility and break down wider perceptions surrounding the community (Table 8).

DISCUSSION

The importance of people and their participation is increasingly recognized as central to the success of the UN SDGs, reinforcing the need to connect top-down and bottom-up approaches to environmental research and policy. Here we evidence the transformative capacity of co-created citizen science and the potential of such approaches to influence behavioral change among co-researchers. The multifaceted benefits associated with participation are empirically highlighted across four diverse community groups with transformations documented at both individual and community levels.

The complexity of the learning process and how this evolves throughout each of the research phases is evidenced across the value creation cycles and highlights the importance of valuing and evaluating the entire research process (Cornish et al. 2023; Greenhalgh et al. 2016). In each project, co-researchers were brought on a journey, and findings reveal that participation provided value within each cycle of the value creation framework (VCF). The first and second research phases (1: education and outreach, 2: co-creation) were linked to intrinsic motivations to engage with projects, such as excitement, interest, and new experiences (immediate value) as well as increased awareness and skills (potential value). Such visible learning outcomes are most frequently cited in the literature and are commonly used to evaluate the value of citizen science to participants (Bela et al. 2016; Phillips et al. 2019), however the importance of such outcomes in driving more complex and multifaceted aspects of learning are rarely investigated.

Qualitave data captured throughout particpatory evaluations illustrates how benefits within each of the value creation cycles are interlinked, and suggests that Wenger et al.'s (2011) VCF provided an insightful means to explore value created through particpation in co-created citizen science. For example, participation significantly enhanced co-researchers' belief that they can contribte to science and environmental research, with feelings of increased confidence and empowerment directly linked to increased awareness as a result of the practical and hands-on activities they experienced. This highlights the importance of moving beyond unidirectional science communication towards active learning processes (Jordan et al. 2011). Moreover, the intrinsic value associated with active learning (immediate value) may contribute to more effective and effcient scientific practice as well as improved science-society-policy interactions (Walker et al. 2021), with evidence suggesting that behaviours driven by intrinsic motivations are more likely to be sustained over time than those driven by extrinsic motivations (e.g., guilt and fear) (Jordan et al. 2011).

The goal of community building generally lies outside of the primary discovery goals of science (Adler et al. 2020), and exising research on the community-level outcomes of citizen science is limited (Jordan et al. 2012). Yet, one of the most interesting results of this study was the importance of the community-building dimension, particularly the way in which participation was percieved to enhance feelings of belonging, connection to the wider community, and community visibility. Our results suggest that social interaction among community groups and academic researchers was important for developing a sense of community, while active participation in project activities were key determinants for co-researchers' shift in perceptions relating to science and research. Thus both community and co-creation inform the transformative social change documented in our case studies, and both should be recognised for their relative importantance in bridging gaps between society and science.

Connecting communities to environmental issues can be challenging, and distrust in science and the scientific community was evident among some co-researchers at the beginning of projects. For example, climate change is often perceived as an issue that affects select countries or future generations (Sutton and Tobin 2011), making it difficult for people to understand impacts on their lives. Embedding local knowledge and lived experience into projects from the start provides local context, fosters deeper connections to the issue, and most importantly, empowers communities—shifting perspectives around who can meaningfully participate in and contribute to environmental research. Feelings that individual or collective actions can bring about change aligns with the psychological construct of "response efficacy"—an important driver of behaviour (Doherty and Webler 2016). In this study, direct links between self-efficacy and behavioural change were evident, with co-researchers reporting raising wider awareness, recycling, and reducing plastic use.

IMPLICATIONS FOR PRACTICE

This research evidences how co-created citizen science can facilitate transformative learning experiences that lead to pro-environmental behaviors, shifts in perceptions, and community building. Our findings hold important practical implications: Firstly, they highlight the importance of paying attention to the relationship building and educational components of citizen science and engaging participants with knowledge self-efficacy through practical and hands-on experiences that connect them to global challenges at local scales while also breaking down perceived barriers such as the accessibility of science. Secondly, our findings show the importance of embedding participatory evaluation throughout the research process to capture co-researcher experiences. Evaluations of citizen science impact are commonly conducted after project completion and therefore reflect the perceptions of scientists rather than participants (Bela et al. 2016). While we do acknowledge limitations to our approach, primarily linked to the use of qualitative data, which can be subjective, a major strength of this study was the richness of data collected through the active participation of all co-researchers in an iterative cycle of reflection and evaluation. This ensured the learning effects reported in each case study reflected the perceptions of co-researchers, with assessments of transformative effects of learning based on empirical data rather than assumptions.

CONCLUSION

If we are to address global environmental challenges and make progress towards the UN SDGs, it is essential that inclusive public participation in scientific research is increased. Our research has shown that co-created citizen science can be an effective approach to engage diverse community groups, drive behavioral change, and shift perceptions around who can meaningfully participate in scientific research. We show that value is created from participation in the activities themselves, not just project outcomes or findings, highlighting the need for ongoing project evaluation that captures impact across research phases from the perspective of participants. We encourage the development of similar co-created initiatives at local levels for pro-longed periods; this develops capacity to address environmental concerns by providing opportunities for diverse groups to connect with marine environments and become actively involved in research that matters to them.

DATA ACCESSIBILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

SUPPLEMENTARY FILES

The supplementary files for this article can be found as follows:

- **Appendix A.** Breakdown of focused group discussions (n = 17) and surveys (n = 58) included in analysis. DOI: https://doi.org/10.5334/cstp.682.s1
- **Appendix B.** Survey Questions. DOI: https://doi.org/10.5334/cstp.682.s2

ETHICS AND CONSENT

Projects were approved by the Ethics Review Board at Newcastle University. Written informed consent to participate was obtained from all co-researchers.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

DR, JD and HS conceived the research idea. DR conducted data collection and analysis. All authors contributed to the writing and reviewing of the manuscript.

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REFERENCES

Adler, F.R., Green, A.M., and **Şekercioğlu, Ç.H.** (2020). Citizen science in ecology: a place for humans in nature. *Annals of the New York Academy of Sciences*, *1469*(1), pp. 52–64. DOI: https://doi.org/10.1111/nyas.14340

Agnew, S., Kopke, K., Power, O.-P., Troya, M.D.C., and **Dozier, A.** (2022). Transdisciplinary research: Can citizen science support effective decision-making for coastal infrastructure management? *Frontiers in Marine Science*, *9*, 809284. DOI: https://doi.org/10.3389/fmars.2022.809284

Ansell, C., Sørensen, E., and **Torfing, J.** (2022). Co-Creation for Sustainability: The UN SDGs and the Power of Local Partnerships. *Emerald Publishing*. DOI: https://doi.org/10.1108/9781800437982

Beaugrand, G., Conversi, A., Atkinson, A., Cloern, J., Chiba, S., Fonda-Umani, S., Kirby, R., Greene, C., Goberville, E., and **Otto, S.** (2019). Prediction of unprecedented biological shifts in the global ocean. *Nature Climate Change*, *9*(3), 237–243. DOI: https://doi.org/10.1038/s41558-019-0420-1

Bela, G., Peltola, T., Young, J. C., Balázs, B., Arpin, I., Pataki, G., Hauck, J., Kelemen, E., Kopperoinen, L., Van Herzele, A., Keune, H., Hecker, S., Suškevičs, M., Roy, H. E., Itkonen, P., Külvik, M., László, M., Basnou, C., Pino, J., and **Bonn, A.** (2016). Learning and the transformative potential of citizen science. *Conservation Biology*, *30*(5), 990–999. DOI: https://doi.org/10.1111/cobi.12762

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., and **Wilderman, C.C.** (2009). Public participation in scientific research: Defining the field and assessing its potential for informal science education. A CAISE Inquiry Group Report. *Online submission*.

Bulkeley, H., and **Castán Broto, V.** (2013). Government by experiment? Global cities and the governing of climate change. *Transactions of the institute of British geographers*, *38*(3), 361–375. DOI: https://doi.org/10.1111/j.1475-5661.2012.00535.x

Colosi, L., and **Dunifon, R.** (2006). What's the difference:"post then pre" & "pre then post.". *Retrieved on August*, *15*, 2009.

Cornish, F., Breton, N., Moreno-Tabarez, U., Delgado, J., Rua, M., de-Graft Aikins, A., and **Hodgetts, D.** (2023). Participatory action research. *Nature Reviews Methods Primers*, *3*(1), 34. DOI: https://doi.org/10.1038/s43586-023-00214-1

Côté, I. M., Darling, E. S., and **Brown, C. J.** (2016). Interactions among ecosystem stressors and their importance in conservation. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1824), 20152592. DOI: https://doi.org/10.1098/rspb.2015.2592

Dawson, E. (2014). "Not designed for us": How science museums and science centers socially exclude low-income, minority ethnic groups. *Science education*, *98*(6), 981–1008. DOI: https://doi.org/10.1002/sce.21133

Dawson, E. (2018). Reimagining publics and (non) participation: Exploring exclusion from science communication through the experiences of low-income, minority ethnic groups. *Public Understanding of Science*, *27*(7), 772–786. DOI: https://doi.org/10.1177/0963662517750072

Doherty, K. L., and **Webler, T. N.** (2016). Social norms and efficacy beliefs drive the Alarmed segment's public-sphere climate actions. *Nature Climate Change*, *6*(9), 879–884. DOI: https://doi.org/10.1038/nclimate3025

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J.P., Fulweiler, R. W., Hughes, T. P., Knowlton, N., and **Lovelock, C. E.** (2020). Rebuilding marine life. *Nature*, *580*(7801), 39–51. DOI: https://doi.org/10.1038/s41586-021-03271-2

Ferreira, J. C., Vasconcelos, L., Monteiro, R., Silva, F. Z., Duarte, C. M., and **Ferreira, F.** (2021). Ocean literacy to promote sustainable development goals and agenda 2030 in coastal communities. *Education Sciences*, *11*(2), 62. DOI: https://doi.org/10.3390/educsci11020062

Fuenfschilling, L., Frantzeskaki, N., and **Coenen, L.** (2019). Urban experimentation & sustainability transitions. *European Planning Studies*, 27(2), 219–228. DOI: https://doi.org/10.1080/09654313.2018.1532977

Geldmann, J., Joppa, L. N., and **Burgess, N. D.** (2014). Mapping Change in Human Pressure Globally on Land and within Protected Areas. *Conservation Biology*, *28*(6), 1604–1616. DOI: https://doi.org/10.1111/cobi.12332

Greenhalgh, T., Jackson, C., Shaw, S., and **Janamian, T.** (2016). Achieving research impact through co-creation in community-based health services: literature review and case study. *The Milbank Quarterly*, *94*(2), 392–429. DOI: https://doi.org/10.1111/1468-0009.12197

Gunnell, J. L., Golumbic, Y. N., Hayes, T., and **Cooper, M.** (2021). Co-created citizen science: challenging cultures and practice in scientific research.*Journal of Science Communication*, *20*(5), 1–17. DOI: https://doi.org/10.22323/2.20050401

Jimenez, M. F., Laverty, T. M., Bombaci, S. P., Wilkins, K., Bennett, D. E., and **Pejchar, L.** (2019). Underrepresented faculty play a disproportionate role in advancing diversity and inclusion. *Nature Ecology & Evolution*, *3*(7), 1030–1033. DOI: https://doi.org/10.1038/s41559-019-0911-5

Jordan, R. C., Ballard, H. L., and **Phillips, T. B.** (2012). Key issues and new approaches for evaluating citizen-science learning outcomes. *Frontiers in Ecology and the Environment*, *10*(6), 307–309. DOI: https://doi.org/10.1890/110280

Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., and **Ehrenfeld, J. G.** (2011). Knowledge Gain and Behavioral Change in Citizen-Science Programs. *Conservation Biology*, *25*(6), 1148–1154. DOI: https://doi.org/10.1111/j.1523-1739.2011.01745.x

Kelly, R., Evans, K., Alexander, K., Bettiol, S., Corney, S., Cullen-Knox, C., Cvitanovic, C., de Salas, K., Emad, G. R., Fullbrook, L., Garcia, C., Ison, S., Ling, S., Macleod, C., Meyer, A., Murray, L., Murunga, M., Nash, K. L., Norris, K., . . . Pecl, G. T. (2022). Connecting to the oceans: supporting ocean literacy and public engagement. *Reviews in Fish Biology and Fisheries*, *32*(1), 123–143. DOI: https://doi.org/10.1007/s11160-020-09625-9

Kieslinger, B., Schürz, S., Mayer, K., and **Schaefer, T.** (2022). Participatory evaluation practices in citizen social science: Insights from three case studies. *fteval Journal for Research and Technology Policy Evaluation*, *54*, 10–19. DOI: https://doi.org/10.22163/fteval.2022.567

Kythreotis, A. P., Mantyka-Pringle, C., Mercer, T. G., Whitmarsh, L. E., Corner, A., Paavola, J., Chambers, C., Miller, B. A., and **Castree, N.** (2019). Citizen Social Science for More Integrative and Effective Climate Action: A Science-Policy Perspective [Policy and Practice Reviews]. *Frontiers in Environmental Science*, *7*. DOI: https://doi.org/10.3389/fenvs.2019.00010

Lewenstein, B. (2019). The need for feminist approaches to science communication. *Journal of Science Communication*, *18*(4), C01. DOI: https://doi.org/10.22323/2.18040301

Maxwell, S. L., Fuller, R. A., Brooks, T. M., and **Watson, J. E. M.** (2016). Biodiversity: The ravages of guns, nets and bulldozers. *Nature*, *536*(7615), 3. DOI: https://doi.org/10.1038/536143a

Moallemi, E. A., Malekpour, S., Hadjikakou, M., Raven, R., Szetey, K., Ningrum, D., Dhiaulhaq, A., and **Bryan, B. A.** (2020). Achieving the Sustainable Development Goals Requires Transdisciplinary Innovation at the Local Scale. *One Earth*, *3*(3), 300–313. DOI: https://doi.org/10.1016/j.oneear.2020.08.006

Phillips, T., Bonney, R., and **Shirk, J.** (2012). Citizen science: public participation in environmental research. (J. L. Dickinson and R. Bonney, Eds.). Cornell University Press. DOI: http://www.jstor.org/stable/10.7591/j.ctt7v7pp

Phillips, T. B., Ballard, H. L., Lewenstein, B. V., and **Bonney, R.** (2019). Engagement in science through citizen science: Moving beyond data collection. *Science education*, *103*(3), 665–690. DOI: https://doi.org/10.1002/sce.21501

R Core Team. (2019). R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., … and **Bonney, R.** (2012). Public participation in scientific research: a framework for deliberate design. *Ecology and society*, 17(2). DOI: https://doi.org/10.5751/ES-04705-170229

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., and **Ludwig, C.** (2015). The trajectory of the Anthropocene: The Great Acceleration. *The Anthropocene Review*, *2*(1), 81–98. DOI: https://doi.org/10.1177/2053019614564785

Stevens, M., Vitos, M., Altenbuchner, J., Conquest, G., Lewis, J., and **Haklay, M.** (2014). Taking participatory citizen science to extremes. *IEEE Pervasive Computing*, *13*(2), 20–29. DOI: https://doi.org/10.1109/MPRV.2014.37

Sutton, S. G., and **Tobin, R. C.** (2011). Constraints on community engagement with Great Barrier Reef climate change reduction and mitigation. *Global environmental change*, 21(3), 894–905. DOI: https://doi.org/10.1016/j.gloenvcha.2011.05.006

Walker, D. W., Smigaj, M., and **Tani, M.** (2021). The benefits and negative impacts of citizen science applications to water as experienced by participants and communities. *WIREs Water*, *8*(1), e1488. DOI: https://doi.org/10.1002/wat2.1488

Wenger, E., Trayner, B., and **De Laat, M.** (2011). Promoting and assessing value creation in communities and networks: A conceptual framework. Ruud de Moor Centrum Rapporten, Open Universiteit, Ruud de Moor Centrum, Netherlands. <http://www.open.ou.nl/rslmlt/Wenger_Trayner_DeLaat_Value_creation.pdf>.

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