Journal of Participatory Research Methods

Robinson, D., Sugden, H., Rao, P., Towers, A., Wysocka, J., & Delany, J. (2024). What Makes an Engaging Environment? Lessons Learnt From Co-Created Research With Diverse Community groups. *Journal of Participatory Research Methods*, *5*(4), 1–23. https://doi.org/10.35844/001c.126299

FULL-LENGTH ARTICLES

What Makes an Engaging Environment? Lessons Learnt From Co-Created Research With Diverse Community groups.

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Keywords: Environment, Citizen science, Co-creation, Transdisciplinary, Participatory research

https://doi.org/10.35844/001c.126299

Journal of Participatory Research Methods

Vol. 5, Issue 4, 2024

Complex socio-ecological challenges such as climate change and biodiversity loss have resulted in an increased focus on the co-creation of knowledge to increase the diversity of those represented by and within research, make research more accessible and ensure research has impact outside of academic contexts. However, guidance and dialogue around the many processes that underpin co-created research remain limited. This perspective piece is informed by practical experience in the co-creation of research with historically underrepresented communities and represents a culmination of our experience and perspectives as academics, artists, community development officers and project workers. First, we share methodological insights, including tools used to identify community concerns and promote engagement in the co-creation process. We then present key guiding principles that we believe are important underpinnings of co-creation including: 1) valuing the entire co-creation process; 2) identifying conditions needed for inclusive co-creation; and 3) participatory evaluation. We also share recommended practices that provide illustrative examples of how guiding principles were addressed in practice across each of our case studies. Recommended practices include - but are not limited to - valuing people not 'check boxes', understanding safe spaces, shared language, and integrating evaluation throughout the research process. Our Findings inform future empirical work on co-created initiatives that have meaningful impact for both society and the environment.

1. Introduction

The urgency and immensity of global challenges like climate change, biodiversity loss, and plastic pollution require humanity to engage with the world and each other in new ways. Such compounding crises are difficult to solve as they are complex and ambiguous with respect to their underlying values and causes (Sol et al., 2018) and are amplified by social injustices at local to global levels (Judd & McKinnon, 2021). Greater inclusion of diverse stakeholders in co-producing knowledge and opening up dialogues for change are crucial for finding ways forward (Pereira et al., 2020). However, scientists primarily engage in their language, in their environment and in ways that are traditionally considered appealing or salient (Bevan et al., 2020). Thus, the already science-engaged become more engaged, exacerbating inequalities regarding who has access to and engages with scientific research.

Transdisciplinary research (TDR) is increasingly recognised as an useful approach for more inclusive scientific research and considered key to accelerating progress towards the United Nations Sustainable Development Goals (Thiam et al., 2021). Defined as a "collaborative research process between researchers and the individuals the research is supposed to engage, benefit, or consider" (Strand et al., 2022), transdisciplinarity is useful for incorporating diverse perspectives and experiences, addressing power imbalances, and building trust between academia and community members (West et al., 2021). TDR involves the systemic integration and co-creation of knowledge through a mutual understanding and recognition of the equal value of different knowledge systems. It has gained considerable interest over the last few decades (Lawrence et al., 2022) and is now widely applied in the fields of health, development, industrial production, education and sustainability (Lang et al., 2012; Pineo et al., 2021; M. Polk, 2015).

Citizen science (CS) is recognised as a pathway for enhancing the exchange of knowledge between academic and non-academic groups and has the potential to facilitate TDR to find informed solutions to 'real world problems' (Agnew et al., 2022; Tauginienė et al., 2020). Described as the active involvement of non-professional scientists in scientific research, CS may be categorised into three practices: contributory, collaborative or co-created (Bonney et al., 2009). Most projects are contributory – relying on participation for data collection only (Hecker, Garbe, et al., 2018; Heinisch, 2017), while in collaborative projects, participants also help refine project design, analyse data and disseminate findings (Land-Zandstra et al., 2021). Such projects are a powerful and cost-effective means of generating extensive datasets (Dickinson et al., 2010), however studies have raised doubts as to whether participants are representative of the wider society, with biases in age, gender, ethnicity, and socio-economic status reported (NASEM, 2018; Pandya, 2012; Pateman et al., 2021).

Co-created research models in contrast, have the potential to be a powerful tool to challenge the traditional bases of knowledge production (Gold & Ochu, 2018). Such models show promising efforts to engage diverse stakeholders [see (Chiaravalloti et al., 2022; Pandya, 2012; E. Polk & Diver, 2020)] in all steps and decisions throughout the research process (Shirk et al., 2012) to collaboratively and iteratively design projects, produce knowledge and disseminate findings (Land-Zandstra et al., 2021). In co-created research, stakeholders can pursue their own research interests (Moustard et al., 2021) designing projects that better account for the local environment, socio-economic circumstances and diverse interests of social groups and individuals (Moallemi et al., 2020). Most examples are found in health and biomedical sciences, including the co-creation of research on mental health issues together with affected people in Spain (Bonhoure et al., 2019) and epidemiological projects linking pollution and health (Gignac et al., 2022).

However, fully co-created research remains rare in citizen science, particularly in an environmental context (Senabre Hidalgo, Perelló, Becker, Bonhoure, Legris, et al., 2021).

When co-creation processes do take place they are often not documented, risking the assumption that co-creation 'just works' once a commitment has been made (Cullingworth et al., 2022). Key knowledge gaps exist in relation to the infrastructure, processes and partnerships that help facilitate co-created research and how this looks in practice (Bonney et al., 2014), particularly in research projects that involve underrepresented social groups (Cullingworth et al., 2022). Moreover, there are relatively few publications that combine the perspectives of academic and non-academic participants in reflecting on their experiences of the process of co-creation, despite the value placed on equal research partnerships (Hart & Aumann, 2013). Greater guidance and dialogue around the many processes that underpin co-creation are needed to facilitate stronger science-society relationships and ensure that opportunities to use citizen science to achieve both positive ecological and social outcomes are realised (Bonney et al., 2014).

This paper represents a culmination of our experience and perspectives as academics, artists, community development officers and project workers. It is informed by practical experience in the co-creation of research with historically underrepresented communities in northeast England. First, we introduce four research projects that we co-created with diverse community groups to address environmental concerns at local levels. Second, we discuss methodological insights and our experiences in the co-creation process. Third we present three guiding principles and eight recommended practices to assist future co-created projects and our conceptual reflection on their practical application in our case studies.

2. Statement of positionality

This research was conducted as part of a project entitled Engaging Environments funded by the Natural Environment Research Council. The co-authors of this paper come from both academic and non-academic backgrounds. Authors one, two and six are academics at varying career stages from an early career researcher to senior lecturers. All have expertise in marine science and a particular interest in participatory research approaches. Authors three and five are passionate about supporting local BME women; author three is a contemporary visual artist and director of a Black and minorities women led community arts project, author five is a community development officer. Author four supports LGBTQ+ communities, raising awareness of key issues LGBTQ+ people face. In the following sections, we use the term co-researchers for the community members of the projects that we worked with and academic researchers or facilitators to describe ourselves.

3. Case-studies

This section provides background information on four co-created environmental research projects that we conducted with diverse community groups (Table 1). The aim of each project was to include co-researchers in key decision-making processes throughout all the research phases, developing equitable co-inquiry between communities and environmental scientists. Academic researchers did not define any research topics or project objectives before starting the co-creation process, however, a prerequisite was that projects focused on marine environmental issues. Projects were approved by the Ethics Review Board at Newcastle University. Written informed consent to participate was obtained from all the co-researchers.

The art-science collaborative used art to explore environmental challenges, bringing together women from Bangladeshi heritage in northeast England (co-researchers, n = 15). In the intertidal biodiversity project, co-researchers (young climate activists and residents, n = 9) from a coastal town in northeast England formed a research team to co-design a citizen science project to record intertidal species abundance, contributing to long-term monitoring efforts in the region. The marine ecological communities project was led by co-researchers (n=10) from an LGBTQ+ community group and aimed to explore diverse environmental perspectives and improve understanding of barriers to participation in research. In the plastic pollution project, women (n = 28) - mainly Eastern European – and their families from an International community group, co-designed a project to document plastic pollution at the coast and assess how this varies at local scales.

4. Research process: co-creation in practice

The following section outlines the main phases of the co-creation process (Figure 1) with an overview of key activities undertaken (Table 2). We also highlight shared and different experiences across projects and key observations relating to tools implemented to facilitate co-creation.

4.1. Partnerships

A key strategy used across all case studies was to partner with community organisations. In three of the projects (art-science collaborative, plastic pollution, marine ecological communities) academic researchers established contact through targeted invitations, first reaching out to key individuals already embedded in and trusted by communities (intermediaries). Co-researchers were then approached during events regularly hosted by the community such as ‘chat and chai’ sessions or weekly skype check-ins. This enabled introductions to take place in a familiar environment and was a successful approach to introduce the Engaging Environments (EE) project, gauge community buy-in, share community values and discuss how they could shape projects moving forwards. Compared to traditional recruitment approaches (e.g. word of mouth, social media), targeted invitations have been shown to be an effective way to reach underrepresented groups (Sorensen et

Table 1. Key characteristics of each case study. Note research phases were iterative and overlapped. Identification includes problem definition and development of research question.

Project	Community	Co-researcher demographics	Approx. duration of each phase (months)	Key project goals
Art-science collaborative	Bangladeshi women's group	Age: 35-44 (11%), 45-54 (55%), 55-64 (34%) Ethnicity: Asian (100%) Gender: female (100%); Employment: full-time (33%); unemployed- not looking (56%), volunteer (11%).	Identification: 1 Co-design: 1 Co-production: 5 Action: 1	To co-create artwork that explores environmental issues. To raise awareness within the wider community.
Intertidal Biodiversity	Youth climate group	Number: 9 Age: <18 (82%); 35-44 (18%) Ethnicity: White (100%) Gender: female (73%); male (27%) Employment: full-time (18%); full-time education (82%)	Identification: 2 Co-design: 6 Co-production: 5 Action: 1	To survey and record intertidal biodiversity in northeast England. To develop skills in data collection and analysis.
Marine Ecological Communities	LGBTQ+ group	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%) Employment: full-time (40%); part-time (20%); unemployed-looking (20%); unemployed-not looking (20%).	Identification: 4 Co-design: 2 Co-production: 6	To explore perspectives around science and the environment. To understand and break down barriers to participation in environmental research.
Plastic Pollution	International women's group	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%).	Identification: 5 Co-design: 2 Co-production: 1 Action: 2	To collect local data on plastic pollution and identify litter hotspots. To connect with local marine environments.

al., 2019) and present an opportunity to build capacity in the community. For the Interdisciplinary Biodiversity project, co-researchers reached out to academic researchers to express interest in co-developing a project after hearing about the EE project at a previous community engagement event where academic researchers gave a series of talks on their research. Monetary incentives were not directly given to co-researchers, however incurred expenses (e.g. travel, food) were compensated for across all projects.

Figure 1. A) Research process. Co-created research develops through iterative cycles, with relationship building and co-evaluation embedded throughout all research stages; B) images represent examples of activities undertaken during each research stage.

4.2. Co-design

The co-design phase focused on identifying research areas of interest (problems), defining possible research questions, and designing the study approach. While all research groups followed the same research process (Figure 1), time spend on each research phase varied substantially (Table 1). The art- science collaborative and intertidal biodiversity projects were first to complete the co-design phase and both had a clear idea of what they would like to investigate. Comparatively, the marine ecological communities and plastic pollution projects found it more difficult to reach a consensus and were less forthcoming with project ideas. The experience made academic researchers realize the importance of activities to increase awareness of local environmental impacts and thus this stage became an iterative cycle of education and awareness and problem definition (Figure 1). While awareness sessions were led by academic researchers, co-researchers collaboratively decided upon the types of activities they would like to participate in shaping sessions around topics of interest or concern to them (Table S3, S4). A detailed breakdown of activities undertaken in each case study can be found in the supplementary materials with an overview of key tools used to facilitate co-creation in Table 2.

Participatory workshops were considered an effective tool share and prioritize ideas in an interactive and informal setting. Workshops followed alternate phases of divergence and convergence to generate ideas in a participatory way (Senabre Hidalgo, Perelló, Becker, Bonhoure, Martine, et al., 2021). Activities in the divergent phase typically included brainstorming activities using post-it notes with co-researchers encouraged to note down as many ideas as possible; convergent phases, facilitated collective decision

making through visualisation, dot voting and focus group discussion. Each workshop ended with reflective group discussions. In the art-science collaborative, focus group discussion identified 5 key topics for exploration drawing on experience from the UK and Bangladesh.

Co-researchers in the intertidal study often raised questions that were beyond the scope of what projects could address including multiple questions relating to climate change and its impact on local marine biodiversity. It was therefore important to manage expectations given project timeframe and spatial scale, thus academic researchers took the lead to suggest alternative questions that were feasible but still aligned with the group's interests (climate change and biodiversity). Comparatively co-researchers in the plastic pollution project quickly agreed that they wanted to compare plastic pollution (type and amount) across local beaches with no input from academic researchers. Two of the projects (art-science collaborative and marine ecological communities) did not develop specific research questions but chose to explore several environmental concerns through a combination of hands-on/ creative practice and focus group discussion. Educational objectives were central to all projects (Table 1) and co-designed alongside project/ research specific goals. Co-researchers from the intertidal biodiversity project wanted to develop key skills relating to data collection and analysis, while other groups looked to improve environmental awareness more generally.

In all case studies, co-researchers found research design challenging and expected academic researchers to take the lead proposing suitable designs and data collection tools. In both the art-science collaborative and marine ecological communities' projects bilateral meetings were held between academic researchers and group intermediaries to outline activities and creative workshops, ideas were then discussed in detail with co-researchers and adapted based on feedback. In the intertidal biodiversity and plastic pollution projects, academic researchers proposed standardized protocols, however co-researchers chose key elements to ensure alignment with community interests. For example, participatory mapping was undertaken to identify priority survey sites in the plastic pollution project while co-researchers chose key species to record in the intertidal biodiversity project.

4.3. Co-production

The co-production phase is the part of the research process that focuses on the collaborative and integrative process of the research tasks (Wibeck et al., 2022), and in our studies relates to data collection, knowledge co-creation, participatory artwork, data interpretation and analysis. The art-science collaborative co-produced works of art relating to key environmental concerns (pre-determined by co-researchers in the co-design phase, Table S1). In the intertidal biodiversity project, co-researchers conducted field surveys between June and October 2022 (Table S2). Species abundance and percentage cover records, along with associated environmental data, were recoded following standardised methodology. The marine ecological

Table 2. Illustrates tools used to identify community concerns and promote co-creation across case-studies.

Tool	Description	Studies using tool	Observations
Co-design - identify community concern			
Focus group discussion	Academic researcher set the scene with introductory talk followed then facilitated in-depth discussions led by co-researchers and community artists.	Art-science collaborative	• Provided in depth information relating to concerns from diverse perspectives. • High agreement among co-researchers regarding which topics they would like to explore further.
Participatory workshop	Co-researchers played an active role and actively contributed to discussions. Interactive brainstorming activities and priority setting using dot voting.	• Intertidal Biodiversity • Marine Ecological Communities • Plastic Pollution	• Interactive activities (i.e. brainstorming) facilitated active participation and better engagement than discussions. • Co-researchers preferred to anonymously share ideas. • Helped to contextualize data with local knowledge and lived experience. • Not all groups had a clear concern or interest they wanted to explore; co-design was an iterative process of education/ awareness followed by problem identification.
Online survey	Survey that uses closed format questions to determine level of concern and interest in a range of topics.	• Marine Ecological Communities • Plastic Pollution	• Useful to collect quantitative data, including ranking of key topics in order of priority/ interest. • Low response rate among both groups.
Co-creation – research question			
Focus group discussion	A round table discussion with potential research questions and ideas pitched to co-researchers for discussion.	• Intertidal Biodiversity • Plastic Pollution	• Developing research questions was more challenging for co-researchers than the identification phase and they were happy for academic researchers to lead on this aspect with their input. • It was important to manage expectation and be transparent about what was achievable given the project timeframe and spatial scale.
Co-design – plan research design			
Participatory workshop	Academic researcher introduced survey protocol/ project format. This was then revised following input & feedback from co-researchers.	All	• Co-researchers wanted to learn from researchers, following standardised methodology to collect data, thus were happy for academic researchers to design the study protocol. • Choosing key elements of the protocol (i.e. which species to record and locations to collect data) ensured alignment with co-researcher needs and interests. • Participatory mapping (plastic project) was a powerful way to engage all co-researchers and embed local knowledge into survey design. • Barriers to participation were identified and addressed in project design.
Training workshop	Academic researcher led training on 1) theoretical concepts; 2) monitoring methodology; and 3) practical activity.	• Intertidal Biodiversity • Plastic Pollution	• Co-researchers most engaged with practical activities (i.e. heading onto the shore and practicing survey protocol). • Provided an opportunity to reflect and adapt on survey approach following practical experience to best suit co-researcher needs.

communities project combined focus group discussion to explore motivations and barriers to participation in environmental research with practical 'hands-on activities' to engage researchers in research processes

(Table S3). Co-researchers in the plastic pollution project held beach clean-up events, following standardised methodology outlined by the UK Marine Conservation Society (MCS).

In practice, the number of co-researchers interested in data analysis was relatively small in all projects. A key exception was a subset (older co-researchers) of the intertidal biodiversity project who wanted to develop skills for their own personal development (two co-researchers were applying for university degrees). Academic researchers therefore led training sessions on data analysis and visualization techniques, with tutorials to apply learnings to data collected as part of the project. Co-researchers then shared and discussed findings with the wider group. For the other projects, data analysis was more of a consultation approach (Jennings et al., 2018) led by academic researchers with data summaries shared with co-researchers. In the plastic pollution project, co-researchers reviewed and built on data by revisiting participatory maps to highlight potential pathways for plastic pollution (Table S4).

4.4. Action

Artwork co-created in the art-science collaborative was displayed at a public exhibition from the 9th August – 18th September 2022. The opening night was attended by >45 guests with co-researchers leading discussions about the project, what the art meant to them and raising awareness of the local environment. Data collected throughout the intertidal biodiversity project was uploaded to the National Biodiversity Network (NBN). Co-researchers from the plastic pollution project outlined community actions to help reduce plastic pollution including: 1) organising a meeting with the local council to discuss the issue and the allocation of resources in the city and 2) organising community meetings in litter hotspots to raise awareness and encourage community action.

4.5. Co-evaluation

Evaluation was participatory with co-researchers actively collaborating in the different stages of the evaluation process (Kieslinger et al., 2021; Mayer et al., 2021). Focus group discussion was the primary tool used with each group (Table 3, Table S5) and considered an effective tool in all projects to facilitate the interconnection between reflection and action, enabling an iterative process of problem identification, co-design, co-production, and action (Figure 1). Co-evaluation was initially used to explore motivations, barriers to participation and group values (Table 3). In the co-production and action phases, co-evaluation provided space to reflect on both the research process and outputs (Kieslinger et al., 2022) with a specific focus on community benefit.

5. Guiding principles and recommended practice

The following section is guided by our collective knowledge, expertise, and practical experience in each of the research projects. We held regular discussions and worked as a team to identify key lessons learnt and define

Table 3. Illustrates tools used to promote co-evaluation and how this was embedded throughout the research process.

Research phase	Goals	Tool	Description
Partnership building	- Explore perceptions of the environment, science, and research. - Explore motivations for participation. - Develop a shared understanding of community values. - Identify and address barriers to participation.	Online survey	Collation of quantitative information relating to project motivations and key topics of interest.
		Focus group discussion	In-depth discussion to identify key barriers and develop a shared understanding of group identity, motivations, and perceptions. Actions to mitigate and address barriers also collaboratively discussed.
Co-creation	- Identify and address barriers to participation. - Ensure project aligns with community interest and values.	Focus group discussion	Discussions held throughout the co-design phase to revise project design/ methodologies. Experience of project so far explored, including enjoyment of activities and shared learnings.
		Reflective notes	Critical reflections from academic researchers and facilitators of how activities went and how they were perceived.
Co-production	- Ensure project is meeting expectations. - Reflect on research process.	Focus group discussion	Critical evaluation of project to date and different activities undertaken throughout the research process. Presented an opportunity to re-conceptualise projects, ways of working and the direction of research processes bases on practical experience.
Action	- Assess perceived impact. - Assess change in perceptions. - Capture learnings (awareness/ skills etc).	Focus group discussion	Collaborative discussion to capture individual and shared learnings and reflect on the value of participation in projects.
		Post project review survey	Surveys included both open-ended and 5-point Likert-scale questions including retrospective post-then-predesign questions to capture self-reported changes in knowledge, skills, attitudes and behaviors. Retrospective surveys help control for response shift bias meant that formal questions relating to knowledge did not need to be asked at the beginning of projects (before relationships and trust has been established. Conducted in person following focus group discussion. The survey was designed in English and translated into local languages where necessary. Responses translated by group facilitators.
		Interviews	Semi-structured interviews conducted to directly assess insights, perceptions and experiences. Opportunity for more in-depth reflection on points raised in focus group discussions. All conducted in person.

guiding principles and recommended practices, we believe are important underpinnings of co-creation. Quotes given below are excerpts from our (co-authors) discussions and reflections throughout the research process (Table 4).

5.1. Guiding principle 1: Value the process not just the outcome

It is important to recognise that science communication is not a static goal or outcome, but a continual process of knowledge co-creation and examination of roles and values (Figure 1). Individual experience should be placed at the centre of co-creation, with an emphasis on engagement activities, quality of relationships and power sharing (Greenhalgh et al., 2016). Co-researchers have their own perspectives, lived experience and interest regarding research topics, thus research activities must connect with their interest and everyday realities. Although co-creation is often considered a linear process, projects in each of our case studies progressed iteratively, with ongoing learning and reflection guiding project design and delivery (Figure 1). Moreover, relationship building was considered a key element of the co-creation process and not separated from research activities. The first three recommended practices are intended to help ensure that initiatives value the co-creation process and move away from measures of academic success to promote community and public value.

5.1.1. Recommended practice 1: Researchers need to shift from a narrow view of impact to a more inclusive lens

There are long-standing issues associated with narrow definitions of success and impact in science, including but not limited to, publication output, citation rates and impact factor. Most academic researchers still take 'science' as their object, and desired research outcomes as the starting point for co-creation (Leach, 2022). But how do we capture the value of co-creation beyond science? How do project outcomes reflect this? Simply applying a label of 'co-creation' does not mean that projects are delivering on their aims. Project impact needs to be defined "by community, for community" and greater value should be placed on small-scale or local impacts.

In our projects diverse impacts were demonstrated in a variety of ways including the display of environmental artwork at a public exhibition, the facilitation of a co-creation assembly to tackle plastic pollution and the contribution of local records to online databases. Moreover, preliminary analysis of qualitative evidence has shown the projects have facilitated transformative experiences leading to pro-environmental behaviours, community empowerment, shifts in perceptions relating to scientific research and community building (Robinson et al., 2024). Although significant, such impacts don't necessarily follow 'pathways to impact' because of impact's marked linearity: defining of project aims, prediction of impact, conduction of research, and reporting of findings (Pain et al., 2015). They do, however, facilitate greater recognition of process driven impact and the importance of not only considering impact as an end product. Impact happens throughout the co-creation process and even beyond the lifespan of a project (e.g. formulation of new research partnerships in the art-science collaborative). Sharing of the diversity of impacts achieved in different contexts is therefore

important and we echo sentiments from Wynne-Jones et al. (2015) and suggest that the experience of researchers using co-creation should be widely shared to inform the impact agenda.

How best to capture impact is also an important consideration and again requires input from all co-researchers. Processes of impact evidence gathering can damage research partnerships by re-introducing hierarchical power relations and conceptions of knowledge (Williams, 2013). Although many environmental problems are tackled through both scientific and social research methodologies, there is still a tendency to weight large quantitative datasets over qualitative data. Qualitative methods – like co-creation – are dynamic, embracing rather than flattening differing perspectives on the same issue. Eliciting voices through qualitative research necessitates research methods which challenge power dynamics, giving power to the lived experience and providing compelling insight regarding context and action. This can ensure outcomes have real benefit within the local community as evidenced in our plastic pollution project where participatory maps and local knowledge provided a much richer and holistic understanding of the issue than quantitative data alone, informing where efforts to mitigate pollution would be most beneficial and which communities should be the focus of future engagement.

5.1.2. Recommended practice 2: Researchers must critically reflect on whether a co-created approach is appropriate and continually reflect throughout all project phases

Researchers, stakeholders and funding bodies have embraced co-production of knowledge to solve environmental and social sustainability problems (Lemos et al., 2018). However, at the beginning of any collaboration, it is important to reflect critically on whether a co-created approach is appropriate (Gunnell, 2021). Honesty is important. What do we really want to achieve? What are the project goals? Are we willing to confront our academic positionality and let go of control of research outcomes? Can we re-think our paths to impact? How do our personal perspectives shape our research and practice? Do our personal perspectives allow us to be flexible and adaptable to develop initiatives that align with the needs of diverse communities? Co-creation will not 'just happen' and researchers must not be complacent about the inherent challenges and change in practice that co-creation demands.

Despite the benefits of co-created research, it might not be suitable or necessary in all contexts and co-creation should not be considered the superior option (Hecker, Haklay, et al., 2018). In many instances a key challenge refers to academics primary commitment to conducting and finishing the research rather than realising sustainable impact afterwards (van Dijk-de Vries et al., 2020). Finding the balance between time and resources in conducting research vs capacity building is a well-known challenge (Froeling et al., 2021) and it is important to ensure there is support for the additional

resources required at an institutional and funding level. Co-creation requires input from all participants and thus it is important to develop research and analytical skills. This may require extensive training and employment, but it is an essential component for ensuring that co-ownership of the project and its results are extended to all members of the community. How academic researchers position themselves in co-created research is therefore an important consideration (Chambers et al., 2022). Here we (academic researchers) aimed to use our expertise to provide technical guidance and training (e.g. intertidal biodiversity surveys and statistical analyses) to help further community agendas while also creating a safe space that broke down barriers to participation and helped co-researchers engage with topics of interest. We also provided guidance on what was feasible within project timeframes and supported framing of research questions based on co-researcher concerns or issues of importance. This approach represents the 'genie' archetype described by Chambers et al. (2022) to facilitate a more inclusive and solutions driven approach to co-creation.

Researchers reflected on challenges and ways of working throughout the co-creation process via individual reflective diaries, focus group discussions, and co-evaluation. Understanding why we are doing co-creation, what this means for all involved and how this aligns with community and individual values was important. Continual reflection also ensured that our projects accounted for the actual needs of the community, in terms of session frequency, length, focus and format.

5.1.3. Recommended practice 3: Value people, not 'check-boxes'

Inclusive engagement and science communication goes beyond 'check-boxes'; it is about valuing diversity, community practices, and people as individuals. Checkbox-style documentation and interpretation of identity assumes deep meaning about a person's way of thinking, despite being formed from minimal data. This can manifest as quick fixes to make sense of a community's beliefs, inequalities faced and barriers to participation - missing the point of deeply understanding differences for genuine, impactful collaboration. Taking time to establish and sustain relationships and trust is central to TDR (Kliskey et al., 2023) and helps to ensure that projects and communication are based on the unique situation and interests of individuals. In our projects, this has been achieved by spending time in communities, spending the day in a local park, having lunch together or going for coffee, showing an interest in personal stories and sharing personal stories of our own. Such activities may seem trivial, but they are rarely done by researchers. Moreover, at the beginning of each project community values were collectively defined and discussed to form the basis of the research project moving forward and guide our collaboration.

5.2. Guiding principle 2: Ensure the appropriate conditions are in place for inclusive co-creation

Co-creation is not just a set of principles that can be implemented, it is more about what conditions need to be met for co-creation to take place. The process of co-creation depends on trust, respect and equitable partnerships which lead to openness and shared dialogue. Different contexts may bring different challenges to co-created projects. However, as presented across our case studies, the following pre-conditions may facilitate project development and implementation across a diverse range of realities.

5.2.1. Recommended practice 4: Recognise the value of intermediaries

Co-created initiatives are often set-up by actors - such as academics – who are distant from participant communities. Counteracting the risk this poses requires guidance from intermediaries who already work closely with, and are trusted by, communities (Stevens et al., 2014). While existing work highlights the key role that intermediaries play in co-creation initiatives (Skarlatidou et al., 2022), the value of partnerships with intermediaries is often insufficiently discussed and financially resourced. Intermediaries are members of a community and as such, understand its conflicts, cultural, physical or economic grievances, and local power dynamics (Merry, 2006) – all of which must be considered before implementing a co-created project. Partnerships with intermediaries give the project legitimacy (Stevens et al., 2014) and importantly in our projects have enabled us to connect and engage communities by: 1) providing critical insight into project design; 2) helping break down barriers to participation (e.g. language); and 3) providing capacity to manage projects locally. Examples of such intermediaries in our projects are local charities and representatives of participating communities including engagement and community development officers.

5.2.2. Recommended practice 5: Take the time to understand what a 'safe space' means to each community group.

Selecting settings that make people feel comfortable can promote diverse voices to be raised fostering creativity and innovation (Thomas et al., 2021). Although definitions of a 'safe space' can and should vary they should always allow for openness, protected communication, mutual respect, and the expression of different opinions. For some the physical spaces chosen for co-creative activities are important. For example, creative workshops with the art-science collaborative were held at a local arts and entertainment venue - a place the women were familiar with and said felt like home. For others it is not always physical but a feeling, a supportive network and being around people that you trust (Table 4). Reflective processes (Bustamante Duarte et al. 2021) were key to understanding safe spaces. Discussions relating to participant identities, barriers to participation and group dynamics allowed collaborative adaptation of projects in response to existing and evolving needs and interests (Table 3). We therefore believe that safe spaces themselves

Table 4. Overview of recommended practices and supporting quotes. Quotes are reflections from project facilitators (community artists, project directors, community development officers) extracted during co-author reflections and team discussions.

Recommended practice	Quotes
1. Researchers need to shift from a narrow view of impact to a more inclusive lens	"Artwork integrated co-researchers' perspectives and opened space to discuss the impacts of climate change and plastic pollution with the wider community". "Rather than report after report it is about having that wider impact and providing opportunities for the group to share their knowledge and show just what they are capable of".
2. Researchers must critically reflect on whether a co-created approach is appropriate and continually reflect throughout all project phases	"Many think that they can contact organisations working with marginalised groups and go on to work with them…. job done. But the truth of the matter is that there is a lot more behind this". "I feel like asking university groups what do you really want to achieve? Is your goal just to sit down with a bunch of black women and that's it or do you really want to change your behaviour and understanding as a result of that?".
3. Value people, not 'check-boxes'	"This has felt like a truly equal partnership with the women at the centre of all decisions".
4. Recognise the value of intermediaries	"Our role as community workers, it's very intuitive a lot of it is based on community development theories but a lot is about the life experience we have, the knowledge of what works, also working with those community groups where there is a sense of equality there which they don't get in the wider society".
5. Take the time to understand what a 'safe space' means to each community group	"There are barriers to accessing the coastline. One of them is confidence and being able to come out, particularly if you have not been out for long. 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 is an important thing".
6. Open communication and shared language	"We need to think about how language can alienate people, especially when working with vulnerable groups or groups who are not engaged with these issues. What kind of language we should be using?". "This is why the arts are exciting, it has capacity to communicate with anyone at various levels".
7. Evaluation as an integrated research activity	"It has been very beneficial to stop and reflect together, to discuss what has worked….it has been great to see this feedback into the project as we move forwards". "Group discussions have really helped capture thoughts, feelings and different perspectives and how they have evolved as projects have progressed".
8. Results of project evaluations should be disseminated	"Universities want to work the voluntary or community sector, but they are often very fixed in their approach, and we have to try and fit. This project has been different, and I think it is important to share our reflections to inform future projects".

are co-created and co-experienced, developed from ongoing and evolving relationships. Establishing ground rules at the beginning of each collaboration helped create an environment where all voices could be heard and treated with respect. Moreover, all activities and workshops were informal, agendas flexible and refreshments available. In both the art-science collaborative and plastic pollution project we ensured a family friendly environment, welcoming their children during weekend or holiday events so that all co-researchers were able to attend.

5.2.3. Recommended practice 6: Open communication and shared language

Co-creation pre-supposes a culture of open dialogue and discussion, bringing together different perspectives to arrive at an informed interpretation of an issue. However, as noted by Cook (2012) "If authentic involvement is to take place, considerable time and effort needs to be allocated during the research process to just talking". Talking was central to all our projects, and included project specific discussion and reflection but also sharing of personal stories and informal chats. This enabled academic researchers to step outside of their official roles and share information about

themselves that was not project related (e.g. hobbies) which helped change group dynamics and create a more level playing field for communication. Although research activities varied across our case studies talking was always combined with practical activities (e.g. art, beach clean-ups) enabling co-researchers to gain new experiences while creatively taking a step back from their everyday lives to openly express their perspectives and experiences relating to research topics. Such active-dialogue based learning was multi-directional and fostered a deeper and mutual understanding of topics.

Language can exclude or include people, activities, and ideas (Dawson, 2014). Thus, one requisite for successful communication and collaboration is to develop a shared language. Our case studies revealed several learnings surrounding language and a need to collaboratively define terms to avoid misunderstanding and misinterpretation (Table 4). Firstly, it is important to recognise that the meaning and emotional loading of words can vary depending on lived experience, and in the context of co-creation between stakeholder groups. Secondly, academic jargon and unnecessarily complicated language must be avoided to ensure diverse audiences can connect with the message being shared. Third, shared language does not have to be spoken, it can, for example, be visual. Finally, dialogues around equity, equality, diversity, and inclusion are broad and growing (Tooth & Viles, 2021). Such terms are frequently used without being properly defined, questioned or without an understanding of what they mean to communities and academic researchers. Our case studies overcame the barrier of language through early and in-depth discussions with group intermediaries which brought greater transparency to the ways in which simple re-phasing of terms can influence community buy-in. We also collaboratively defined key terms and group values and, where required, had translators present throughout all activities (Table 4).

5.3. Guiding principle 3: Participatory research requires participatory evaluation

While it is widely accepted that research evaluations should consider the entire process (Schäfer & Kieslinger, 2016), approaches towards the evaluation of research activities typically focus on assessments of project outcomes against a set of pre-determined standards and criteria. Such top-down, pre-structured assessments do not align with the collaborative and inclusive nature of co-creation, which calls for context-specific and tailored forms of evaluation that consider motivations, expectations and challenges experienced by all, as well as socio-cultural impacts (Kieslinger et al., 2022). It is important to consider evaluation as an integrated research activity with participants engaged in conversations beyond research outputs and quantifiable measures of 'success' at the start of, and throughout, the research process. Giving voice to co-researchers in the choice of evaluation instruments and criteria through the collective definition of expected project outcomes has been labelled co-evaluation by Mayer et al. (2021).

5.3.1. Recommended practice 8: Evaluation should be an integrated research activity

In our projects co-evaluation was not only focused on project learnings and outputs but also used to identify and overcome barriers (Kieslinger et al., 2022) and develop new ways of working collaboratively. A range of evaluation methods were used (Table 3) to integrate both qualitative and quantitative data (For additional examples of co-evaluation tools, see Arnold and Mundy 2020; Sardo et al., 2022). However, across all projects focus group discussion was the primary evaluation tool as co-researchers felt most comfortable in group settings and enjoyed building on ideas in informal settings. Embedding co-evaluation throughout the research process (Table 4, Table S1-S4) ensured that reflection and action became and iterative process that translated into evidence-based change and continuous improvements to project design, development, and delivery (da Cruz Pires, 2019). Key examples include adaptation of survey protocols in the intertidal biodiversity project and adjusting workshop format to better suit the needs of co-researchers in the plastic pollution project (Table S2, Table S4). Importantly, co-evaluation helped facilitate continuous control of the research process among co-researchers (Kieslinger et al., 2022) – a key component of all co-created initiatives seeking genuine community collaboration and/or leadership.

5.3.2. Recommended practice 9: Results of project evaluations should be disseminated

Above we have highlighted the importance of obtaining feedback based on participant experience and perspective, however it is equally important that this data is fed back into the development and implementation of future initiatives. Given the limited guidance and dialogue about the research practices and conditions needed for co-creation it is important to disseminate findings via peer-reviewed publications, websites and national or international conferences. As evaluations of individual projects accumulate, meta-analyses or systematic reviews should be used to collate general lessons or challenges to better inform co-created research (Beier et al., 2017).

6. Conclusion

In this era of unprecedented environmental change, we can no longer afford to decouple societal considerations and natural systems. Inclusive approaches to scientific research are urgently required and will involve due exploration and redress of power dynamics and equitable research partnerships with greater consideration of what 'voices' need to be heard. Co-created research redefines relations between academic researchers and community partners, triangulating knowledge from diverse perspectives for a more inclusive and transformative process. Here we have provided our perspective on co-creation informed by our practical experience in co-created citizen science projects that extend beyond scientific value. Our findings

are summarized as guiding principles and recommended practices for future empirical research with historically underrepresented groups. Contextual processes applied and lessons learned across our projects will support redefining or breaking down barriers in participatory science to foster more inclusive scientific research. Although each of the projects had an overarching goal of connecting communities to their local environment and raising awareness of key environmental issues, individual projects remained dynamic and driven by an iterative co-design process. Key themes emerging throughout each of our projects include: 1) the need for researchers to slow down, unpack and value the entire research process; 2) the importance of identifying conditions needed for effective communication and collaboration; and 3) the value of participatory evaluation.

Acknowledgments

We are very thankful to all co-researchers for their time and commitment to each of the projects. This research was conducted as part of a project entitled Engaging Environments funded by the Natural Environment Research Council (Grant number: NE/S017437/1). We are thankful for the valuable discussions that were held with our Engaging Environments colleges with special thanks to Dr Erinma Ochu.

Conflict of interest statement

The authors have no conflict of interest to declare.

Data availability statement

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

Submitted: February 08, 2024 EST, Accepted: April 18, 2024 EST

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