Co-designing citizen science: Principles and guidance

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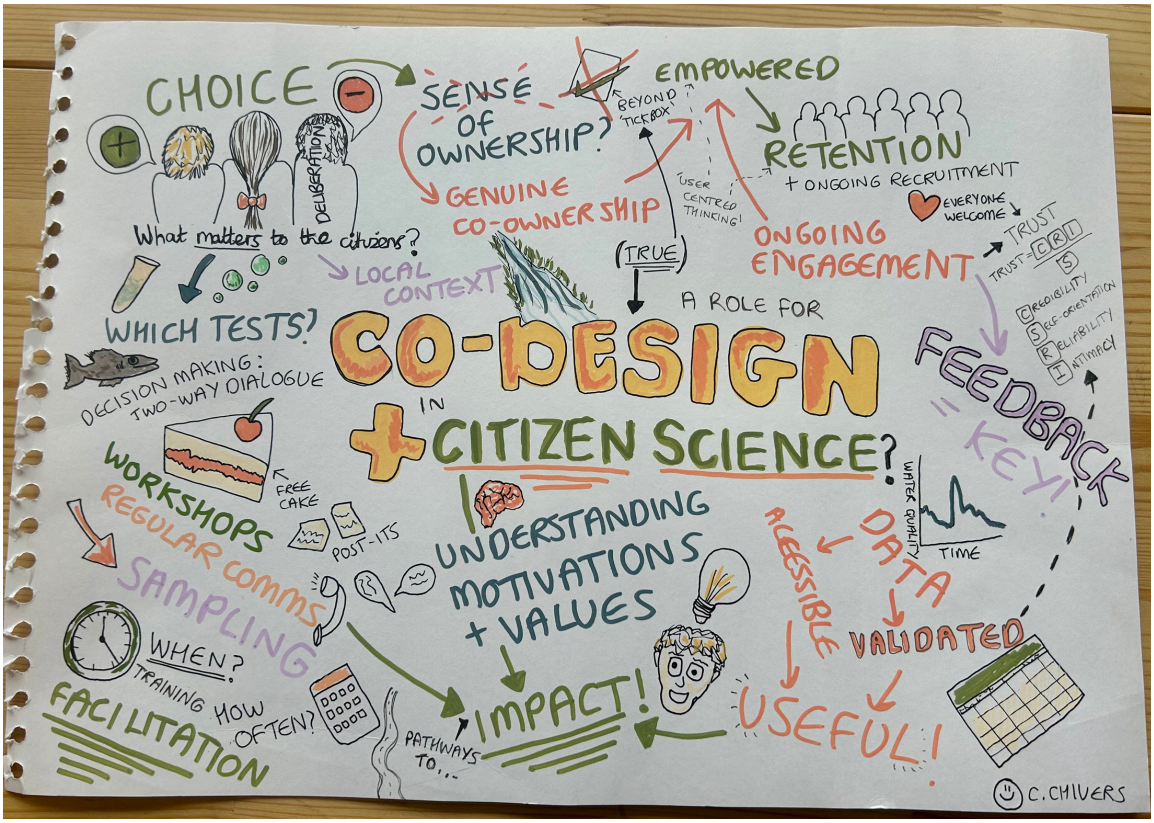


Figure 1: Illustration of how co-design may support citizen science projects
This visual summary highlights the multiple ways that co-design - involving citizens in shaping the aims, methods, and processes of a project - can strengthen citizen science.

Executive summary

This report sets out principles for including aspects of, or, where appropriate, full co-design in citizen science projects. It draws on research carried out during CaSTCo, including case studies (Soil SmARt and River Guardians), interviews with scientists, stakeholders and citizen scientists, and a review of existing literature. Together, these sources inform 12 key principles for guiding co-design.

While some projects, especially those focused on producing robust, scientifically sound data for short periods of time, may not suit full co-design, aspects of the approach can - and as this report suggests - *should* be included. This often takes the form of bounded co-design, where citizens shape some but not all decisions. Including citizens in this way requires recognising the value of local and experiential knowledge alongside scientific expertise. When implemented well, co-design can increase motivation, retention and long-term monitoring, though time pressures, resource constraints and the need for skilled facilitation remain barriers.

Co-design can bring wider benefits such as community building, learning and wellbeing, but may also create challenges, for example where volunteers experience frustration with institutions or anxiety from repeated exposure to poor environmental conditions. Addressing these requires transparency, responsiveness and support throughout. Recognition of contributions, and early planning for legacy, are also essential to sustaining engagement.

We recommend involving citizens even at the planning stage, supported by a clear co-design plan. By combining flexibility with transparency, co-design can strengthen both the robustness and the relevance of citizen science while ensuring outcomes that matter to the communities involved.

Contents

01 | Introduction: CaSTCo

CaSTCo has provided the first national framework for improved, integrated water environment data, integrated modelling capabilities, openly shared collaborative platforms and decision support tools driving environmental improvement.

The programme has involved collaboration between 24+ UK partners, in our case including the Countryside & Community Research Institute, Southern Water, Rivers Trust, Agronomists, agricultural land managers, and wider citizens.

CaSTCo is distinctive in that it sought not only to generate high-quality monitoring data, but also to transform the relationships between citizens, regulators, and industry in how that data is produced and used. By embedding citizen science within a wider framework of protocols, platforms, and governance, the project demonstrates how communities can become trusted partners in evidence generation rather than peripheral observers.

To support this integration, CaSTCo has developed a tiered framework for citizen science monitoring (see Figure 2). This framework recognises that not all forms of participation look the same: some activities prioritise mass involvement and broad spatial coverage, while others focus on rigour, precision, and quality assurance. The tiers range from Tier 0, where large numbers of volunteers contribute simple observations, through to Tier 3, where highly trained participants and professional scientists undertake advanced monitoring. Together, these tiers create a complementary system that balances inclusivity with scientific robustness, ensuring that every level of participation has value in building a fuller picture of river health.

Two CaSTCo initiatives that illustrate these principles in practice include **Soil SmARt** and **River Guardians**. Soil SmARt has co-designed a citizen science project with farmers and land managers to develop practical, participatory approaches for soil monitoring and stewardship, highlighting how citizen science can bridge agricultural practice and environmental objectives. River Guardians, by contrast, has mobilised community volunteers to monitor and protect local rivers, with a strong emphasis on empowerment, feedback, and collective responsibility. Both projects show how CaSTCo's principles of collaboration, rigour, and openness are being operationalised on the ground, turning abstract frameworks into lived practices that generate both data and democratic value.

Co-design is at the forefront of CaSTCo, with several catchments using it to varying degrees.

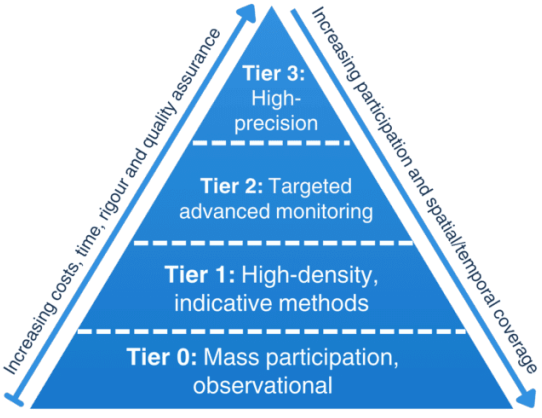


Figure 2: CaSTCo's tiered framework for citizen science monitoring

02 | Co-design and Citizen Science

What is co-design in the context of citizen science?

Co-design is a participatory approach, where groups of people - often from a wide range of backgrounds and motives - collaborate to create viable, legitimate solutions to shared issues. This means that projects and interventions are designed 'with' rather than 'for'. Successful co-design, where people with vested interests are included right from the start of endeavours, can provide an inclusive, fair way of seeking solutions.

In environmental citizen science, co-design is a collaborative approach in which scientists, practitioners, citizen volunteers, and anyone else interested in the project, work together to shape a project's aims, methods, and outputs. It moves beyond the contribution of data alone, involving participants in decision-making across the research process; from identifying questions and selecting monitoring approaches, to interpreting results and planning dissemination. This shared ownership aims to produce citizen science that is both scientifically robust and locally relevant, ensuring outcomes are meaningful to the communities involved (Shirk et al., 2012; Bonney et al., 2009; Vohland et al., 2021). We anticipated that citizens, who often participate in such projects on a voluntary basis, may be more willing to remain involved in such projects if they have had meaningful opportunities to take part in decision making and project planning. **Where citizen science is truly co-designed, these projects may be better referred to as collaborative monitoring,** which may better reflect the shift towards citizen-*led* projects rather than traditional top-down approaches.

Co-design should be treated as more than a 'tickbox' exercise, with focused efforts and facilitation training needed to ensure participants are given full opportunities to negotiate, agonise, and make decisions together. Where true co-design isn't deemed possible, for example, where funding constraints or programme commitments make including citizens in initial decision making difficult, 'bounded co-design', as used in CaSTCo's River Guardians project (p10), offers a pragmatic approach. This is where co-design is included wherever possible - the approach doesn't necessarily have to be 'all or nothing'. Here, transparency is crucial for setting clear expectations with the citizens about where their input will be valued and used for meaningful decision making.

02 | Co-design and Citizen Science

The extent of co-design in existing citizen science

To date, there have not been many explicitly co-designed citizen science projects. For those which are citizen-initiated and led, this is because the resulting projects may be less formalised, with little opportunity to examine approaches taken, particularly as such processes are often organic and impulsive in nature. For projects run by NGOs or researchers, funding and time constraints have likely limited the extent of co-design, despite its potential for boosting retention and long-term sustainability of such projects. Just a few examples of co-design were identified, most of which were about urban-based citizen science. However, the quote below suggests that while co-design hasn't been adopted a great deal to date, researchers have been suggesting approaches that align strongly with the approach:

> **"Fostering project formats that allow participants to get involved in the whole research process from posing the study question to implementing results - could enhance the transformative aspect of citizen science at a societal level"**
> **–** Turrini et al (2018)

Case study: co-designed citizen science - eDNA in the Upper Bure, Norfolk

One clear example of co-design took place in the Upper Bure catchment in Norfolk. Here, National Trust volunteers who were already highly engaged in citizen science in the area were involved in designing a new project for understanding the impacts of various pressures on fish biodiversity in the river. The co-design here involved workshops, participatory mapping, and ongoing evaluation. As a result of the co-design, citizens explained that having the opportunity to identify sampling locations were invaluable and that the knowledge sharing opportunities helped to bring the group together. These participants also explained that they felt that they had contributed to a 'worthwhile endeavour'. The research team also recognised the value of including co-design, as it enabled a two-way exchange of understanding and knowledge. Read more about this study via Clarke et al (2023).

Applicability of co-design for informing citizen science projects

Based on the success of wider research projects that have been co-designed, and Soil SmARt , a CaSTCo co-designed citizen science project, we recommend that future efforts should incorporate co-design as it can help to achieve several of the characteristics of good citizen-led science.

02 The Soil SmARt co-design process

Soil SmARt, a CaSTCo project based in the Arun and Rother is run by Western Sussex Rivers Trust, Southern Water, S. Woodley Crop Services and CCRI. The project used co-design principles to ensure everyone collaborating had ownership of the project through ongoing involvement in decision making.

A mixed methods approach was used to support the co-design, including:

- A rapid evidence assessment to inform our approach around co-design and social learning
- Co-design workshops to decide on methods and approach
- Reflexive training based on citizens' needs
- Iterative co-planning
- Co-selection of a data recording mechanism
- Preliminary and final evaluation interviews (in-person and remote)
- Ongoing engagement via a periodic newsletter and WhatsApp

As shown in Figure 3, we followed a double-diamond approach: evidence and inception work informed problem definition, iterative co-planning and training developed the methods, and delivery was accompanied by ongoing evaluation. The feedback loops illustrate how insights from participants continually shaped subsequent steps.

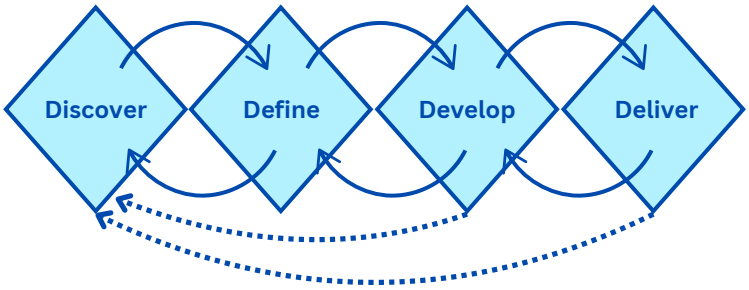


Figure 3: A double diamond approach, with additional feedback loops, informed the co-design of Soil SmARt.

Co-design touchpoints

Regular workshops were carried out to plan the project:

1. Initial inception workshop to explore motivations and ambitions, including identifying which aspects of soil health the land manager volunteers were most concerned about
2. Prioritisation workshop to determine which soil health tests to include in the project, how resulting data should be recorded, alongside how it should be presented and exploited.
3. Training session informed by citizens' pre-agreed requirements
4. Ongoing phone calls and in-person meet-ups to carry out ongoing evaluation

Test selection

Upon being presented with a wide range of soil health tests suited to citizen science, Soil SmARt farmers chose which soil health tests they would like to carry out, based on:

1. Interest - both personal and agronomic
2. Time requirement during sampling
3. Potential for informing farm practices

Once selected, the project team produced a suite of simple, visually appealing instruction sheets, which were laminated for use in the field.

The tests selected by the group are provided in Appendix 1.

02 The Soil SmARt co-design process

Recording data

Discussions about how to record and store data were held during a workshop, with conversations ongoing afterwards, including during and after the bespoke platform training and the first round of sampling. When exploring options for recording data, we did not use a digital-by-default approach because wider studies suggest that this is not appropriate in rural areas with potential connectivity issues, or with farming communities who may have limited inclination or capacity to adopt digital technologies. Participants were, however, keen to explore digital options. The team investigated several platforms for recording such data, including Soil Health (Earthwatch), LandPKS, AHDB, before presenting them all to the land managers alongside benefits and limitations of each. After much deliberation, the land managers collectively agreed that they would trial SoilMentor, as it was well known to them and deemed relatively straightforward to use.

Reflexive training

- Half-day workshop to train citizens on sampling
- All equipment provided, along with engaging instruction sheets
- Full training on data recording, including Soil Mentor

Post-sampling iteration

True co-design requires flexibility wherever possible. Evaluation interviews after the first sampling campaign were carried out to find out how it went and whether the farmers felt able and willing to carry out further campaigns.

Based on suggestions from a few of the farmers, and a general agreement that the extensive suite of tests chosen by the farmers was too time consuming for them, we adapted the second campaign to include a buddy system.

Introducing a buddy system

The buddy system proposed by the farmers was the idea that bringing in a wider citizen scientist to support with sampling would greatly reduce the time requirement. In addition, they agreed that this would be a strong opportunity for them to engage with members of the general public, who may lack understanding of farming and soil health. There was, therefore, a good justification for trialling a buddy system. Soil SmARt began to trial this as an approach but constraints associated with project timings made it difficult to arrange with the farmers.

Future projects working with farmers as citizen scientists should further explore whether a 'buddy' system may help to boost retention and engagement, as well as providing social and educational benefits.

A critical issue: Time

Most farmers are short on time, largely due to heavy workloads and administrative burdens (O'Shaughnessy et al, 2022). This was a challenge throughout Soil SmARt.

By giving the farmers ownership of the project through adopting aspects of co-design, this helped to boost their interest in the project. Largely due to their ability to shape the project and choose tests useful to them, we hope that co-design provided them with additional motivation to take part.

However, at certain times of year their busy schedules limited their ability to engage despite continuing to express interest. Here, longer-term funding for projects is needed so that monitoring campaigns aren't planned for the busiest periods in the farming calendar.

02 Co-design and River Guardians

River Guardians is a successful CaSTCo project based in the Arun and Rother catchment area, led by the Western Sussex Rivers Trust. Over 160 volunteers have become involved in collaborative water quality monitoring.

From the outset of River Guardians, co-design was presented as central to the project, yet the process carried inherent tensions common to many funded initiatives. The volunteer coordinator emphasised the early "pub workshops," describing them as deliberately open-ended and designed to capture volunteers' motivations and concerns. "*There was no plan then really… we just listened to them and saw what they wanted. That was really important because they'd lived by the rivers for 20–30 years, while I'd only been here for a couple*" (Volunteer coordinator).

However, the co-design did not begin with a blank slate. As with most funded projects, the Rivers Trust had agreed deliverables under the national Catchment Systems Thinking Cooperative (CaSTCo) framework. As a result, the volunteer coordinator admitted arriving at initial workshops with preconceived ideas about what parameters might be monitored, guided by discussions with the Environment Agency and Southern Water, experts in the field. This was appropriate as the ultimate objective of the project was to gather accurate data, which inevitably requires expert input. Co-design featured to some extent, in that volunteers influenced certain decisions, including highlighting their interest in clarity, local outfalls, or bacteria testing. These preferences were filtered through what was technically feasible, affordable, and scientifically robust. As the volunteer coordinator put it, "*We had to merge what the experts wanted with what the volunteers thought needed monitoring. Some things we just couldn't do, like bacteria, even though people really wanted it.*" This provided a pragmatic approach to co-design which volunteers seemed broadly content with, in particular as any decisions made that did not immediately appease everyone were explained transparently.

Not all volunteers sought the same level of involvement in the co-design of the project. Some were content to "just get on with the job" of monitoring, while others were eager to shape project priorities or lobby for additional tests. Co-design thus operated on a spectrum of participation: the project opened opportunities for input but did not assume equal appetite for decision-making across all volunteers.

After the initial consultation, co-creation shifted towards a more managed cycle of engagement. Every six months, the volunteer coordinator convened large-scale meetings, asking volunteers to reflect on their experiences and priorities using post-its and facilitated exercises. Co-design was, however, limited: the locus of decision-making sat increasingly with the project team, who synthesised volunteer feedback and reported back with revised tools (e.g., changes to equipment or new ways of presenting data). As the volunteer coordinator acknowledged, this was partly pragmatic: "*We just knew we had to capture people, hear what they want, and then try to deliver on that.*"

In this sense, River Guardians exemplifies a form of "**bounded co-design**": volunteers' voices shaped the contours of the project, but within the parameters set by funders, scientific standards, and managerial interpretation. The volunteer coordinator recognised both the value of consultation and the limits of shared decision-making; a tension likely familiar to many externally funded citizen science initiatives.

03 Perceptions towards co-designed citizen science

To examine perceptions towards co-design and how it contributes – or could contribute – to citizen science, we interviewed a total of 48 citizen scientists, scientists, and wider stakeholders. While true co-design is rare in existing citizen science projects, there appears to be a clear role for either aspects of the approach, for example where including citizens in decision making won't affect the accuracy of the resulting data, or where appropriate, full co-design.

Scientist interviews

We interviewed 10 scientists from a range of institutions, career stages and disciplines took part in our interviews. The participants included hydrologists, hydrological modellers, soil scientists, system scientists, catchment scientists, hydrogeologists, citizen science researchers, and ecologists.

Stakeholder interviews

Stakeholders, or anyone involved or interested in citizen science that isn't working as a scientist, or taking part in citizen science as volunteers were interviewed, many of whom run citizen science projects, or are considering doing so, in the future. Organisations represented by the 10 interviews carried out included government bodies, including senior members, various environmental NGOs, private initiatives, and SMEs.

Citizen scientist interviews

We carried out interviews with 28 citizen scientists involved in a wide range of projects beyond CaSTCo. This allowed us to capture a broader sense of the extent to which co-design features in existing projects, alongside whether citizens feel they would like such processes to take place.

Soil SmARt and River Guardians evaluation interviews

A series of 18 evaluation interviews were carried out with citizen volunteers and project team members involved in two CaSTCo projects: Soil SmARt and River Guardians. Here, we draw on some of this evidence.

Analysis

The interview data, together with observations made during the Soil SmARt and River Guardians initiatives and relevant published literature, were examined systematically using self-determination theory as the guiding conceptual lens (see pages 9-10, Chivers et al, 2025). A thematic analysis approach was adopted to identify recurring patterns, points of divergence, and novel insights.

Quotations are included throughout the report to illustrate the lived experiences of participants and to demonstrate how our interpretations are firmly grounded in the data. These are attributed as follows: CS(number) for citizen scientists, RG(number) for River Guardians, SS(number) for Soil SmARt, SH(number) for stakeholders, and SCI(number) for scientists.

This process led to the identification of a clear set of principles for co-designing citizen science. These principles reflect not only what participants said but also the underlying motivations, constraints, and aspirations evident across groups. The recommendations presented in this report therefore rest on a transparent and robust analysis, ensuring that they are both empirically grounded and practically relevant.

03 Volunteers' views of co-design for citizen science

Volunteers involved in citizen science projects beyond CaSTCo reported that they have had limited opportunities to input into project design. According to citizens, including co-design in future projects could: 1) Improve relevance and flexibility; 2) Enhance motivation and retention, and 3) Strengthen data quality and innovation. This could also help citizen science to move away from communication gaps, overcome expert-volunteer divides, and avoid rigidity in methodologies where appropriate.

Current extent of co-design

Interviewed citizens generally reported having limited opportunities to provide meaningful input during the design of citizen science projects. Even when enthusiastic to contribute suggestions, a few volunteers reported that organisations seldom follow up. One citizen described offering their thoughts on a new tool, only to be ignored: *"They asked us what we thought about it… which was just completely ignored. And we were seen as trouble."* (CS21)

In contrast, aspects of co-design appears to be happening more in smaller, volunteer-led groups. One citizen involved in a community-run initiative emphasised local ownership: *"We own the data… we're only feeding into the wider system… it feels different emotionally… this is ours, and we're running it."* (CS14)

Co-design for overcoming barriers

According to citizens, co-design could increase the efficiency of co-design by overcoming:

Communication gaps and responsiveness: Frustrations arise when volunteers' queries go unanswered—or when organisational processes feel impersonal. Structured co-design forums (e.g. steering groups with volunteer reps) can ensure voices are heard.

Expert-volunteer divides: Volunteers perceive a knowledge barrier. Co-design workshops can demystify methodologies while respecting volunteers' local expertise, bridging both perspectives.

Rigid methodologies: One "nationwide" tool allowed recording only where mud enters rivers, ignoring volunteers' wishes to trace its source upstream. Involving volunteers early could have prevented this misalignment.

Potential of co-design to contribute to citizen science, according to citizens:

Improve relevance and flexibility

Co-design could allow volunteers to tailor approaches to local contexts, e.g, by choosing sampling points meaningful to them. This can also help to avoid over-burdening participants: **"***There needs to be a willingness… to adapt the project to meet the requirements of the volunteer and accept that you might not get the perfect data."* (CS9)

Boost motivation and retention
Giving citizens a genuine stake in certain decision making fosters responsibility, competence, and continued engagement: *"There has to be a benefit for the volunteer… they're giving up their time… there's got to be a selfish perspective for it."* (CS9)

Strengthen data quality and innovation
Volunteers are often good at identifying practical solutions for making sampling more efficient (e.g., adding a simple plastic sheet under sampling trays, or laminating paper sheets). Regular two-way feedback can give citizens the opportunity to share their ideas - in particular as many are proven to be experts themselves, with most interviewed volunteers coming from a scientific/environmental background themselves!

Real-Life Examples of co-design in existing projects

- **Volunteer Representatives on Steering Committees:** In one river trust project, two volunteers sit on the project steering group, ensuring every planning decision considers volunteer needs and practicalities.
- **Group Mapping Exercises:** A project split volunteers into small teams to map potential sampling sites on OS maps, then conducted field "recces" together—fostering ownership and practical feedback before finalising the strategy.
- **Locally Initiated vs. Umbrella Projects:** Comparing a small volunteer-led group (Friends of Gledhow Valley Woods) with the larger Rivers Trust highlights how scale influences co-design: the former enjoys total freedom to innovate, while the latter operates under fixed national standards. Volunteers noted both the strengths and limitations of each model.

03 Scientist and Stakeholder perceptions towards co-designed citizen science

To examine perceptions towards co-design and how it contributes – or could contribute – to citizen science, we interviewed 20 scientists and wider stakeholders.

Scientists and stakeholders consistently recognise co-designed citizen science as both powerful and effective, yet they observe it is still rarely implemented in full. While true co-design is rare in existing citizen science projects, there appears to be a clear role for either aspects of the approach, for example where including citizens in decision making won't affect the accuracy of the resulting data, or where appropriate, full co-design.

Key reasons identified by scientists and stakeholders to adopt co-design in citizen science

01 Empowerment and ownership

Co-design makes volunteers feel invested and genuinely valued. Where monitors set monitoring priorities, volunteer retention is improved.

02 Trust and relationship building

Rapport building, ideally through long-term networks support ongoing and new participation.

03 Usability and relevance

Co-designed protocols and training are more likely to align with their needs – top-down project planning can miss what the citizens care about the most and fail to recognise their skills and expertise.

Co-design for boosting motivation

"The bottom-up kind of approach, where citizens tell you what they want to monitor, what they're concerned about and where they want to monitor, leads to more sustained engagement, which is of course needed. Traditional citizen science is very top-down: the scientists from the university will have everything already in place for the citizen —'This is what you're gonna do, this day you're gonna collect, this way.' And maybe that's not what the citizens actually care about, so they become less engaged because of that." (SH5)

Co-designing for retention

"When it's co-designed—because citizens are already involved—they know how important it is. But if you dictate tasks, even when necessary, it's harder: if it's not a regular six-monthly survey, they'll forget and lose interest. In those cases, you often have to check in more frequently with extra feedback on where the data's going and what it's showing, plus some meetings or training to keep the momentum. Whereas if it's co-designed from the beginning, they're already invested: they understand what it is and can even create other activities between monitoring rounds. If there's a six-month gap between datasets, they might design another survey or task in the meantime to keep the group together. Ultimately, staying in touch is really important." (SH7)

Co-designing for rapport

"If you establish these networks, the co-design piece becomes much easier because you build up the rapport and the relationship… then you can have a proper in-depth conversation (…) Engaging with citizens in can really help deliver co-designed citizen science." (SCI3)

Co-design for fostering trust

"If you're involving people in things like co-design, which can be incredibly powerful and effective, you need that longevity really to be able to actually kick things off on the ground and you need to be able to, depending on the specific situation, do things like build trust, build that sense of community and actually allow things to grow". (SH4)

03 Scientist and Stakeholder perceptions towards co-designed citizen science

Co-designing citizen training

The co-design of training used in Soil SmARt resonated with other interviewees, who emphasised the importance of flexible, engaging training:

"I would co-design the training with citizens, rather than just inviting them into a classroom… getting them to come in and ask what are your knowledge gaps, what are you interested in?… then tailor the design of the learning to suit those needs. And hopefully by being part of that co-design process, they feel empowered… and they feel like they have an actual foot under the table, as opposed to coming in and just undertaking training". (SCI2)

Meeting data requirements

Some participants felt that it is important to have a strong understanding of the desired impact and aim of citizen science projects, with all interests represented:

"Yes, there's a strong focus on co-creation… you want to know it's usable and makes sense for the users… ask what data people need and want from it, keep it simple and clear for the users. So you'd need a lot of different people in the room I think. It all depends...it starts further back than that in terms of what you're trying to do with it. Are you trying to get data or are you trying to have create behaviour change, or is it both? And what's possible?" (SH2)

Case study: Striking a balance between co-design and rigour - a monitoring approach in Gloucestershire

A scientist interviewee provided an overview of how they became involved in an activist group's citizen science project. They found that by being included in the project, they were able to support in making its outputs more scientifically viable and thus more impactful. Co-design was recognised as important for much of the project's organisation - including developing a sampling strategy:

"What we did in the meeting was capture participants' initial thoughts and ideas before developing the strategy. We split them into three groups—East, Central and West—and had them highlight suitable areas on OS maps. One team didn't draw anything, so we encouraged them to go out and do a recce… so different approaches were used by each group but then I think everyone's on board with the strategy." (SCI9)

However, certain aspects of the project that were recognised as non-negotiable and thus not suitable for co-design. For example, risk assessment is a necessity that cannot be negotiated as it concerns citizen safety.

Barriers to the adoption of co-design in citizen science: scientists' perspectives

Resource and practical constraints
Co-design requires time, effort, and resources, which means it often remains aspirational. However, the initial investment can lead to more efficient and impactful projects, making it worthwhile in the long term.

Need for accurate, robust data
Scientists may be hesitant to cede control where data quality is at stake. Transparency about which decisions citizens can influence helps balance scientific rigour with participation. While protocols may remain fixed, elements like training can be co-designed. Nonetheless, scientists should compromise where possible to ensure genuine ownership for citizen volunteers.

Top-down project design
Citizen science is often structured through top-down models prioritising consistency and rigour. While this protects data quality, it can reduce volunteer agency, engagement, and innovation.

Expertise and power divides
An expert-lay divide persists. Scientists acknowledged the value of local knowledge but noted that citizens are often excluded from shaping research questions or methods, reinforcing hierarchical structures.

Performative participation
Where citizen input is ignored, participation risks becoming tokenistic. Scientists noted that volunteers feel frustrated when feedback is dismissed, though practical constraints such as limited time and funding often play a role.

04 Pathway to co-designed citizen science

The pathway below provides guidance on how to integrate co-design in citizen science projects. The extent to which co-design is appropriate is project-dependent, and for many projects, it may be suited for certain stages and not others. This pathway can be used alongside the principles that follow, thus providing a full toolkit for including aspects of – or even full – co-design in citizen science projects.

STAGE	HOW TO CO-DESIGN?	KEY REQUIREMENTS
Ideation	Asking prospective volunteers and target audiences what they would like a potential citizen science project to explore, e.g., via vision-setting workshop, including volunteers on steering groups	• Stakeholder mapping • Initial engagement with potential volunteers and representatives from key organisations • Facilitation skills, e.g., trained social scientist
Protocol development	Presenting potential sampling techniques and methods to ensure minimal barriers to participation, e.g., practicality, relevance to the volunteers	• Willingness to compromise • Awareness of potential barriers (e.g., simplicity of tests, digital aspects where relevant) • Ability to explain scientific rigour and methods
Training	Training preferences – timings, location, upskilling, familiarity	• Capacity building skills • Equipment provision • Flexibility in terms of timings
Monitoring	How, when, and frequency of sampling, based on volunteers' preferences If demands are too high, retention is likely to be low Discuss expectations from both sides	• Flexibility in expectations • Ongoing check-ins • Validation and verification • Regular feedback
Analysis & Interpretation	Citizen requirements of data – how should it be analysed, interpreted and presented so that it is useful to them? Wider key audiences may require a different approach again (e.g., differing levels of detail)	• Analytical skills • Ability to interpret and translate results into accessible findings • Applying findings to practical solutions
Communication & Engagement	How do citizens want to stay in touch and in which formats? How often? How will feedback and validation be provided? Who should the main point of contact be?	• Regular and ongoing contact • Readily available volunteer coordinator with strong facilitation skills
Outreach & Impact	Many citizens may be well connected and able to support – who do they know? Who do they want to reach?	• Wider networks, e.g., with policymakers, public sector • Relationship building • Two-way dialogue about desired impacts

05 Principles for including co-design in citizen-led science

The remainder of this report presents 12 key principles for guiding the inclusion of co-design in citizen science.

These principles were developed based on on CaSTCo's Soil SmARt and River Guardians' respective co-designed processes, a synthesis of existing literature, and a series of interviews (see page 12).

The infographic to the right provides an overview of these principles, while the following sections provide detail about each point, including practical guidance for achieving them.

These principles can help to inform all stages of future citizen science projects, from ideation through to delivery (see p15).

Principle 1 | Co-create a shared vision

Develop the project's aims collaboratively with citizens from the outset. Clarify both the purpose and the scope for participant input to set mutual expectations.

Here, it is important to have an understanding of citizens' intrinsic and extrinsic motivations and contexts to ensure that the project is likely to meet their needs and interests. Familiarity with the various types of motivations and self-determination theory is helpful here (see pages 9-10, Chivers et al 2025).

Effective facilitation is crucial for ensuring that citizens feel able to voice their views and concerns. Holding in-person workshops and events can provide a good opportunity for co-creation, particularly where participatory activities are planned.

What does the wider literature say?

Literature supports our evidence that early-stage involvement fosters a sense of ownership, improves long-term engagement, and ensures the project is grounded in the priorities and perspectives of the community involved.

Examples: Turrini et al (2018); Golumbic et al (2015)

Case study: co-creating a vision - Soil SmARt

Workshops were held to develop the goals and approach for Soil SmARt. While the vision was not fully co-designed from the beginning - as the broad remit of the project had been pre-determined when securing funding to deliver the project - so the focus was always going to be on soil health. However, the exact aspects of soil health to be examined was co-designed based on the citizens' (i.e., land managers') preferences. Here, activities included open discussions about key barriers and enablers to engagement, and participatory prioritisation exercises. Choosing soil health tests to use was crucial for informing the vision. Here, land managers were presented with the full suite of possible tests, before participating in a prioritisation exercise. The tests that they were most interested in were taken forward for a first round of monitoring, on the basis that further adjustments could be made throughout.

Identifying citizens' challenges and interests → **Exploring potential citizen science tests/approaches for solving the identified challenge(s)** → **Co-developing the 'how'**

Principle 2 | Foster transparency and trust

Integrity and trust is crucial to any citizen science project, co-designed or otherwise. Clearly communicate which elements are open to co-design and which are fixed (e.g. due to funding or regulatory constraints). Be open about limitations and revisit them collaboratively as the project evolves. This is a crucial aspect of building trust, which is critical for any successful project.

Citizen science projects are rarely co-designed from the outset. On the most part, this is because projects require funding - and current approaches leave limited scope to include citizens in bidding processes.

In addition, there may be some aspects of data-driven citizen science projects that scientists and stakeholders deem non-negotiable, for example to maximise robustness and accuracy. By explaining the parameters of the co-design from the beginning, this will manage expectations of the citizens.

Where decisions are made by particular groups, e.g., scientists, effort should be made to explain why. For example, if a particular testing regime is to be used, the scientists should explain the benefits (and potential limitations) and make it clear how the approach is likely to maximise the impact of the project, and thus the ability of the citizens to solve the challenge(s) they wish to solve.

What does the wider literature say?

Trust is strengthened when participants understand the rationale behind decisions and the scope of their influence (Sauermann et al., 2020). Meaningful and appropriate data collection is essential for achieving trust and in citizen-gathered data and therefore its use. While this may limit the potential for co-design in some cases, aspects can still be included. Quality assurance - from all perspectives - should happen at the project design stage, including methodologies and training of participants and project managers (De Rijck et al. 2020). These approaches are likely to elicit trust both among citizens and the intended audiences for the gathered data (e.g., regulators, policymakers).

The following quote from Holliman et al (2024) demonstrates the importance of achieving trust, particularly if citizen science requires accessing people's land: '*The word trust is really important. I'll never forget a moment when we walked up a hill in the Chilterns. Me and C, it was on the second or third walk and C said: 'Thank you for letting me in and trusting me. This is your space that I've entered.' I am a 'safe space' holder and before letting C in I built a relationship with her to ensure that her motives and approach felt ethical, honest and kind. She showed a real sense of empathy and it felt genuine'.*

Embedding transparency: River Guardians

CaSTCo's River Guardian's project benefitted from a volunteer coordinator who was well liked and trusted by the citizens. While co-design aspects featured throughout the project, the tests and equipment used were determined by the Rivers Trust to maximise accuracy. This was discussed in a workshop setting, with multiple opportunities for citizens to voice concern. This transparency led to broad acceptance by the citizens, who appreciated being kept informed and that the chosen approach was most likely to yield valuable data, using the most cost effective kit possible based on the expertise of the Rivers Trust and the wider scientific team involved in CaSTCo.

Importance of honesty when things go wrong...

Learning is a crucial aspect of co-design. Even best laid plans can go wrong, avoidably or otherwise. For example, data may be gathered - or analysed - incorrectly, or facilitators may misconstrue discussions. It is crucial that unanticipated challenges, mistakes or oversights are communicated with citizens so that they feel respected. Acting with integrity is key, even if it at first feels uncomfortable to admit mistakes. By discussing challenges with citizens, they may support in finding solutions and may feel more connected to the wider project team.

Principle 3 | Effective facilitation

Effective facilitation will foster open discussion and citizen retention. Be mindful of power dynamics and emotional impacts, and promote a supportive and respectful environment throughout.

Several scientists, citizens, and wider stakeholders emphasised the importance of good facilitation in citizen science projects, including during co-design processes. This facilitation is often delivered by volunteer coordinators and the wider project team. After explaining the importance of trained scientist involvement in citizen science for maximising robustness, this citizen science participant demonstrated that there is also a strong need for an experienced facilitator and communicator on such projects:

"*There are also professionally trained engagement people who are experts at getting people to join in and in a coordinated way. Now, just because you can design a brilliant sampling technique which is as reliable as it can be, if it's not attractive to the non science population, it's not off the ground. And you also need professionals who can then take the data and present it in a way that means it will convince decision makers to take action". (CS23)*

Case study: River Guardians

The volunteer coordinator, Keir Smith, for River Guardians was widely recognised as a natural facilitator, able to create a warm, inviting environment during workshops and training. His approach was characterised by integrity - staying true to promises such as providing six-monthly opportunities for sharing results and feedback. The engagement of more than 160 volunteers is in large part due to his effective facilitation.

Volunteers consistently praised his ability to make them feel valued: "It's about having the regular meetings that he has… and then he produces those things showing us the health of the river. It's regular communication, I think really" (RG04). Others emphasised the practical support he offered as coordinator: "He trained us and he monitors our data… we get feedback from him to say our results have been accepted. He usually leads the evening sessions, and if you need any extra equipment then he provides them" (RG13).

Keir Smith, Western Sussex Rivers Trust

For many, Keir was the driver of the project, offering both leadership and personal support. As one participant put it, "*Kier Smith is excellent… he's really good, drives things on, gets a lot done. I think he's transformed that organisation*" (RG12). At the same time, volunteers voiced concern that such knowledge and commitment were tied to a short-term contract: "*His knowledge… is terrific. Are you going to get somebody of that knowledge on a one-year contract?*" (RG15). Together, these reflections underline that effective facilitation in citizen science is not incidental but central for building trust, sustaining engagement, and ultimately enabling collective action.

What does the wider literature say?

Some research has emphasised the importance of avoiding extractive interactions with citizens and land managers involved in participatory research, instead cultivating deliberative spaces where disagreement is welcomed as part of an agonistic, constructive decision-making process (Barry & Ellis, 2014; Adamsone-Fiskovica & Grivins, 2022).

Key barriers: Time, funding, facilitation training

Importance of local facilitation

Having locally available volunteer coordinators is key for effective facilitation: "*They recognise that they need more than one coordinator within West Country Rivers Trust. Our coordinator was in Plymouth so for her to come all the way to us it's a long way, so it doesn't happen much. It won't happen - and if you try to then get people together for some sort of social, which they couple of years ago, the same problem is you had to be really enthusiastic and be able to afford to give time and petrol costs and everything to go. So it's difficult and that's why you need local volunteer coordinators... and I know how difficult they are to get.*" (CS21)

Principle 3 | Effective facilitation: Practical guidance

Create an inclusive environment: At the outset, set a tone of openness and respect. Use introductions or low-pressure activities to help participants feel comfortable contributing. Make it clear that all perspectives are valued, regardless of background or experience. Establish shared ground rules for how the group will communicate and collaborate.

Build rapport and be approachable: Developing trust and positive relationships is central to effective facilitation. Take time to get to know participants, learn their names, and show genuine interest in their motivations for joining the project. Be friendly and approachable, and respond promptly to questions or concerns. A warm, informal tone can help reduce barriers to participation and encourage ongoing engagement.

Avoid defaulting to top-down approaches: Facilitators may unconsciously slip into directive roles, especially if they are used to leading structured projects. Supporting co-design often requires unlearning habitual ways of working and embracing a more collaborative mindset. This includes letting go of control where appropriate and resisting the urge to provide immediate solutions. Holding space for uncertainty, exploration, and shared decision-making is essential.

Support balanced participation: Pay attention to group dynamics and use techniques that encourage input from everyone: These might include small group tasks, written prompts, or simple turn-taking. Adapt your approach to suit online or in-person settings, and use a mix of spoken, written, and visual formats to accommodate different communication styles.

Be clear about scope and expectations: Explain what aspects of the project are open to co-design and where constraints exist, such as fixed methods or funder requirements. Revisit this regularly to manage expectations and maintain transparency.

Use accessible tools and formats: Support structured discussions with tools that help groups generate, organise, and prioritise ideas. These might include whiteboards like Miro, visual mapping, or voting exercises. Avoid jargon and ensure materials are easy to understand.

Facilitate disagreement constructively: Differences in opinion can be valuable if handled well. Encourage open discussion of different perspectives and help participants explore compromises where needed. Use neutral framing and keep the group focused on shared goals.

Check in and adapt: Build in time to reflect on how the process is working. Short feedback rounds or informal check-ins can highlight what's working and what might need adjustment. Be prepared to adapt your facilitation style in response.

Encourage shared responsibility: Where appropriate, involve participants in helping to run sessions, lead discussions, or share findings. Provide light-touch support to help them take on these roles confidently. This builds capacity and reinforces a sense of shared ownership.

Record and acknowledge input: Keep a visible record of decisions and suggestions, and share this with participants. When ideas cannot be acted on, explain why. This reinforces trust and shows that contributions are taken seriously.

Principle 4 | Embed meaningful decision-making

Move beyond consultation to genuine collaboration. Create space for citizens to influence key decisions, where appropriate, and where they would like to be involved. This may include aspects of project design, data interpretation, and dissemination.

Where citizens are told they will have decision making power, it is crucial that such processes happen with integrity. Here, it is thus important that the parameters of their decision making are clearly stated. Wherever flexibility and compromise is possible, volunteers should be given opportunities to help shape projects - if they would like to. In some cases, citizens may prefer to leave decision making to scientists or other project team members - but that is a decision in itself, that they should be able to make.

Case study: Soil SmARt

Citizen land managers involved in Soil SmARt were given ongoing opportunities to inform and make changes to the project.

In some cases, decisions were made that were inconvenient to the project team and risked affecting the scientific rigour of the project. For example, after the first round of soil monitoring, the farmers collectively agreed that they wouldn't be willing to complete the full suite of tests next time. Compromise was crucial here, and negotiations took place to ensure that the most critical tests would be completed based on the citizens' interest and willingness.

Inviting citizens to take part in decision making can also result in innovation. Having found monitoring too time consuming as farmers, the volunteers suggested a willingness to work with wider citizens to complete the soil sampling. This led to the ideation of an innovative approach to monitoring for farmers - a buddy system, where a non-farming citizen would assist in soil sampling. By allowing the citizens to have decision making power, this led to more experimental and novel citizen science.

Impact of citizen science

Citizens should be given opportunities to determine how project findings are shared. For example, if they are motivated by a desire to secure clean water in their local rivers, there may be particular audiences they personally wish to reach, e.g., local policymakers, water authorities and companies, regulators. Giving them the chance to brainstorm ways of making the data impactful may give them more ownership of the project and motivate them to support with dissemination and awareness raising efforts.

Case study: WildTracker study

The WildTracker study demonstrated that when citizens were involved as equal partners throughout the process - from design to dissemination - they were more likely to engage in pro-environmental behaviour and sustain their involvement over time (Taylor et al., 2023).

Principle 5 | Encourage inclusive and accessible engagement

Citizen science has gained recognition as a valuable means of environmental monitoring and public engagement, but concerns remain around its accessibility and inclusivity, particularly in marginalised communities. Co-design, which involves participants in shaping the design and implementation of projects, offers a pathway to address these challenges. However, its application must be carefully tailored to context, objectives, and the realities of participant capacity.

Opportunities through Co-Design

- Co-design enables more flexible, context-sensitive participation models that accommodate diverse lived experiences. By engaging stakeholders in early planning, projects can:
- Identify barriers to participation (e.g. childcare, transport, digital access).
- Integrate multiple participation formats (e.g. in-person, low-tech, asynchronous).
- Increase relevance to underrepresented groups through locally meaningful goals.

Successful approaches include:

- Modular participation options for those with limited time.
- Targeted outreach through trusted community figures.
- Incentives such as travel stipends or integrating CS into paid roles.
- Such strategies help address the structural constraints that many face, including financial insecurity, multiple jobs, and limited free time. These conditions make unpaid environmental monitoring a low priority for many.

Caveats and Context Dependence

Despite its promise, co-design is not a panacea. As Pateman and West (2023) highlight, CS still struggles to engage diverse publics, even where benefits to marginalised communities are clear. A key tension lies in balancing innovation with operational sustainability. Retired, well-educated participants are often the backbone of CS efforts, and bring reliability, skill, and motivation. Their contributions, while often undervalued, are essential and should not be displaced or forgotten while (rightfully) attempting to increase diversity in citizen science.

Moreover, the aim and remit of a project matters. Efforts to promote equity, diversity, and inclusion (EDI) may be most effective where CS offers tangible, immediate benefits to marginalised communities. For instance, air or water quality monitoring in areas affected by environmental injustice may resonate more than more abstract goals. Where intrinsic motivation is lacking (NASEM, 2018), material or social incentives may be necessary.

There is a legitimate concern about opportunity costs: directing funds toward inclusive engagement might initially yield modest returns in participation. Yet, diversity should not be pursued solely for scale; instead, it should be realised as an opportunity to enhance legitimacy, improve knowledge pluralism, and strengthen CS's role in environmental justice.

Recommendations

- Continue to leverage committed participants already active in CS.
- Pilot scalable, low-cost models to broaden access, and document the tensions transparently.
- Treat diversity as an evolutionary goal, not an immediate metric.
- Reframing diversity efforts as integral to the future-proofing of citizen science can help reconcile short-term efficiency with long-term societal value.

Principle 6 | Value local knowledge and experience

Respect and mobilise the expertise citizens bring. Allow decisions to be shaped by their interests and insights, even where this requires adjusting conventional scientific approaches.

Citizen science projects often walk a line between meeting externally defined research objectives and responding to local priorities. While funders and professional scientists may come with pre-set deliverables, projects that build in scope for locally relevant concerns are more likely to secure commitment and long-term engagement. For example, in River Guardians, volunteers highlighted pollution from specific outfalls and agricultural run-off as issues of concern; shaping monitoring around these insights helped ensure data felt meaningful to them. Literature on participatory research stresses that when projects acknowledge and integrate local knowledge into aims and protocols, this enhances both the scientific robustness and the legitimacy of findings (Bonney et al., 2016; Shirk et al., 2012). Conversely, if project aims are too rigid, volunteers may feel their knowledge is undervalued or tokenised. The scope of projects should therefore be negotiated rather than imposed, striking a balance between scientific comparability and local responsiveness.

The following quotes, extracted from interviews with 44 citizen scientists, scientists, and wider stakeholders, demonstrate the extent of expertise and knowledge held by many citizen scientists.

These quotes provide further evidence that citizens can, and should, be involved in decision making, and that the resulting data may, in many cases be more meticulously gathered than has been assumed in the past. Data gathered, in particular en masse, is likely to be broadly indicative of trends as while there may be outliers, there will be a weight of evidence - seemingly gathered by well qualified individuals on the most part, in particular where there has been a strong training component to the project.

"I'm retired now. I've worked all my career for a company called ADAS, which used to be part of the Ministry of Agriculture, and [my spouse] worked for a private environmental consultancy company. At various times, I have been a crop centre scientist, a horticultural researcher, and a professional ecologist for 30 years". (CS02)

"I'm a medical doctor. I'm also a local councillor and I'm chair of our local climate action team. So that that was the way sort of into citizen science. But as part of my background, during A levels I did some water quality work on the local river measuring biological auction demand. So I have sort of vaguely done this sort of stuff before". (CS11)

Citizen scientists as experts

Our interviews with a wide range of citizen scientists, scientists, and stakeholders, revealed that a high proportion of volunteers come from scientific or environmental backgrounds. Many of these citizens have a strong understanding of water quality, in some cases based on decades of professional experience.

In addition, citizens involved in such projects are often motivated to do so because of their attachment to the particular place being monitored. Here, they often have extensive knowledge about the local area, making them well placed to groundtruth data and support in choosing monitoring sites. Incorporating opportunities for citizens to share and mobilise their knowledge and experience is, therefore, crucial.

Riverfly citizen science is one strong example of this, with citizens able to sample in increasing detail based on their experience and expertise, either from their backgrounds or capacity building and training achieved through their participation in the project. In some cases, train the trainer approaches offer an opportunity for citizens of varying degrees of experience to teach, or be taught.

Principle 6 | Value local knowledge and experience (continued)

What does the wider literature say?

Citizens, including land managers, often hold an intimate understanding of their environment. This knowledge can bring valuable insights that would be inaccessible via standard scientific methods alone (Oliver et al, 2012; Heinisch, 2021). Projects that acknowledge this expertise improve both data quality and participant commitment.

Most citizen scientists interviewed come from a scientific or environmental background.

Practical recommendations

- **Create pathways for expertise recognition:** Provide opportunities for citizens with specialist skills (e.g. in hydrology, ecology, or farming) to contribute beyond basic monitoring, such as site selection, advanced testing, or mentoring others.
- **Use flexible training models:** Adopt "train the trainer" or tiered accreditation schemes, enabling experienced volunteers to build capacity within their own networks and extend the project's reach.
- **Design participatory scoping exercises:** At project inception, use workshops or mapping activities to elicit local knowledge about pollution hotspots, historical changes, or land use practices, and incorporate these into monitoring plans.
- **Embed feedback loops:** Show volunteers how their local insights shaped decisions (e.g. choice of sites, testing methods). This prevents disengagement and reinforces the value of their contribution.

Case study: Soil SmARt

Soil SmARt was informed by the expertise and knowledge of land manager citizens throughout. For example, they were able to determine which fields and sites should be surveyed based on their agronomic experiences on their land. Their knowledge of soil health was also key when deciding on which soil health tests to carry out.

Policy suggestions

- **Institutionalise citizen expertise:** Encourage agencies such as the Environment Agency, Natural England, or Defra to formally recognise citizen-generated data when supported by validation protocols, ensuring that local knowledge influences regulatory decisions.
- **Develop certification frameworks:** Establish national standards for advanced citizen training (e.g. in water chemistry or soil testing), so volunteers with proven expertise can be trusted with more complex methods, reducing reliance on professional staff.
- **Promote co-governance models:** Embed citizen representatives in catchment partnerships or advisory boards, ensuring that local knowledge shapes not only data collection but also decision-making about water management priorities.
- **Ensure funding supports inclusivity:** Resource should be allocated to allow projects to adapt to diverse forms of knowledge, including the experiential expertise of landowners and the cultural/ecological knowledge of communities often marginalised in formal science.

Principle 7 | Make space for iteration

Co-design in citizen science should be understood not as a one-off exercise but as a dynamic and evolving process. Treating co-design as ongoing enables continuous responsiveness to the complexities of real-world implementation, particularly when working with diverse publics, stakeholders, or community partners.

Embed Reflection and Feedback
Schedule regular points for structured reflection and feedback throughout the project. These exchanges, whether via socials, workshops, conversations, or surveys, enable participants to surface challenges and shape improvements, reinforcing trust and shared ownership.

Adapt to Changing Contexts
Social, environmental, or institutional conditions, and participant circumstances, may shift over time. Flexibility in design and timing helps maintain relevance and inclusivity, reducing the risk of disengagement.

Stay Responsive
Be willing to revise key elements such as methods, tools, or roles in response to feedback or context. Responsiveness helps maintain alignment with shared goals while ensuring the process remains practical and inclusive.

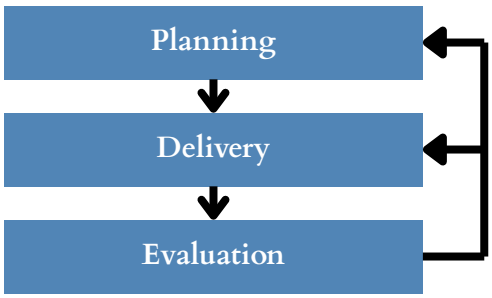


Figure 3: Iteration in practice. A simple operational cycle with feedback loops returning to earlier stages. This makes explicit the dotted feedback loops in the double-diamond model (page 8) by showing how reflection points and participant input trigger re-planning during a project.

What does the wider literature say?

Our rapid evidence assessment confirms that co-design should not be confined to a single project stage. It is an iterative, adaptive process that should accommodate feedback, changing needs, and shifting understandings over time (Zulkafli et al., 2017). Going beyond citizen science, it is widely accepted that iteration between all affected groups increases the production and usefulness of resulting knowledge due to balancing scientific aims as well as user (i.e., citizens') needs and contexts (Dilling & Lemos, 2011).

A useful example of iteration in practice is provided by Neset et al (2021), who co-designed a citizen science climate service. Here, the regularity of iterations was dependent on need and availability according to all involved.

Case study: building flexibility into Soil SmARt

Agricultural land managers were the citizen scientists for Soil SmARt, a CaSTCo project in Western Sussex. Here, flexibility was paramount as participants not only participated voluntarily but also faced heavy workloads demanded by farming. Flexibility was embedded throughout the project by:

- Providing the citizens with a selection of dates for meet-ups and workshops
- Using the largest window of opportunity for monitoring possible so that volunteers were able to do their soil sampling whenever suited them best
- Reflecting and iterating the project design itself via a ongoing evaluation. For example, while the citizens chose a wide range of tests for the first round of sampling, they were able to focus in on a smaller number of tests for the second round after reflecting that their original selection was too ambitious based on their limited availability.
- Some participants dipped in and out of the project, which was also welcomed as we recognised that some involvement is better than none at all.

Flexible timings

Ongoing reflections and iteration to maximise retention

Principle 8 | Recognise Wider Benefits (and Costs) of Participation

Acknowledge and document outcomes beyond data generation, such as community building, wellbeing, skill development and learning, increased environmental awareness, as legitimate and important project impacts.

Co-designing citizen science projects helps to unlock broader social and environmental impacts, which extend well beyond data generation. These include:

Community Building: Co-design fosters local ownership, strengthens relationships between participants, and supports long-term community cohesion.
Wellbeing and Purpose: Meaningful involvement can enhance participants' wellbeing by providing a sense of contribution, recognition, and shared purpose.
Skills and Learning: Collaborative design supports skill development in ecological monitoring, data interpretation, and critical thinking.
Environmental Awareness and Stewardship: When volunteers help shape project goals and methods, their understanding of local environmental issues deepens, supporting pro-environmental behaviours.
Equity in Impact Evaluation: Acknowledging outcomes such as learning, empowerment, and community benefit alongside data quality supports a more holistic model of success.

Co-design ensures that citizen science is not only scientifically valuable, but also socially relevant and inclusive. These wider outcomes should be documented and treated as legitimate impacts in their own right.

Wider benefits of citizen science

Personal benefits:

- Empowerment and agency
- Enjoyment, satisfcation, and fulfillment
- Escape and solace
- Mental wellbeing
- New experiences
- Physical activity
- Recognition or validation
- Self-discovery and identity growth
- Showcasing local knowledge
- Skill development

Interpersonal and community benefits:

- Community pride, including visibility and recognition
- Connection to community - people and place
- Intergenerational or cross-group connections
- A feeling of representing the cause
- Social connections

What does the wider literature say?

The literature here is relatively limited, but suggests that wider benefits of water-related citizen science are more likely to happen with deep, participatory co-design, and are absent in more extractive models of citizen science (Druschke & Seltzer, 2012; Taylor et al., 2023). Pocock et al (2023) provide useful insights into the benefits of biodiversity-related citizen science for nature-noticing, wellbeing, and positive behaviour change, many of which appear to occur for citizens taking part in river-based citizen science. However, it appears that some citizens engaged in water quality monitoring face negative wellbeing implications - in particular where they are monitoring due to severe pollution which has prevented them from undertaking their chosen hobbies, e.g., wild swimming, angling.

The potential costs of citizen science voluntarism

While citizen science creates opportunities for people to contribute to environmental monitoring, it also carries risks. Interviews highlighted how repeated exposure to pollution data can trigger frustration and anxiety. One citizen reflected that "*the more I knew, the more the research I did … I pretty much stopped swimming*" (CS28), describing how monitoring water quality turned a beloved local river into a source of worry. For others, regularly recording poor results was "miserable" and sometimes demanded deliberate withdrawal to protect mental health: *"today I'm not going to be testing because I'm protecting my mental health*" (RG15). **Co-design offers a route to mitigate these downsides.** By enabling citizens to shape their involvement, projects can better balance demands with personal capacities. Providing timely feedback, acknowledging volunteers' contributions, and showing where their efforts lead to tangible change are critical for sustaining motivation. Ensuring that volunteers feel respected, connected, and supported may offset the personal costs of participation and maintain citizen science as a rewarding and impactful practice.

Principle 9 | Share Data and Results Responsively

Disseminate findings in accessible, meaningful ways. Respond to participants' interests and ensure outputs are relevant, practical, and open where possible.

Integrating dissemination into project design: Dissemination is often treated as a final step, but co-design allows it to be embedded from the start. Engaging participants in early conversations about how findings should be communicated helps ensure that outputs are accessible, relevant, and tailored to their needs. This approach improves the likelihood that findings will be understood, shared, and acted upon within the communities involved.

Producing accessible and meaningful outputs: Co-designed dissemination enables the development of materials that reflect participants' preferences and local context. Volunteers may prioritise concise summaries, interactive visuals, or locally tailored maps rather than traditional reports. Tools such as ESRI StoryMaps, QGIS Cloud, and Datawrapper can support the creation of engaging and non-technical outputs, particularly where spatial data is involved. These formats make findings more digestible for diverse audiences, including schools, local groups, or policymakers.

Enhancing practical use and application: Outputs developed collaboratively with participants are more likely to be practically useful. For example, citizen scientists may identify opportunities to feed results into local planning processes, river catchment partnerships, or community engagement events. Where possible, findings should be produced in open and shareable formats, supported by transparent agreements around data access and governance. Hosting outputs via community websites or open repositories such as Zenodo or Figshare can increase their visibility and reach.

Supporting interpretation and communication by participants: Co-design also strengthens capacity by involving volunteers in interpreting and communicating findings. With appropriate support, participants can take active roles in presenting results at public events, writing blogs, or contributing to local discussions. This reinforces ownership and can also help build communication skills and confidence among volunteers.

Sustaining engagement and trust: Ongoing responsiveness to how findings are used, whether they inform action, policy, or further research, is essential. Co-designed dissemination fosters transparency and reinforces participants' sense of contributing to something meaningful. When dissemination reflects shared goals and values, it helps maintain trust and sustain engagement well beyond the formal end of the project.

What does the wider literature say?

Rüfenacht et al. (2021) highlight that dissemination of citizen science findings should become an integral, two-way process from the outset. They stress the importance of early stakeholder engagement in shaping communication channels and methods to ensure accessibility and relevance.

Research has found that CS projects led by professional scientists (as well as by NGOs) don't tend to undertake engagement in a participatory way as they lack communication preparedness, particularly via digital channels (Giardullo et al, 2023). When using digital tools such as collaborative websites or apps to share citizen-gathered data, these should be co-designed and aligned with participants' preferences (Zulkafli et al., 2017; Rollason et al., 2018). To maximise inclusivity, projects should avoid assuming a 'digital by default' approach.

Sharing preliminary Soil SmARt findings

The training that took place as part of CaSTCo's Soil SmARt citizen science was as co-designed as possible. Volunteers were asked to indicate what they'd like to be provided with, both in terms of information and monitoring equipment. We were also reflexive with the level of detail involved.

Upon deciding to use a digital platform for uploading data, it was also decided among the group that having a live, in-person demo from a SoilMentor representative would be helpful.

The duration and timing of the training was also decided by the farmers, who preferred a half day morning session between farming activities.

Principle 10 | Build Capacity and Confidence

Training in citizen science should be co-designed to build capacity not only for data collection, but also for interpretation, application, and critical engagement.

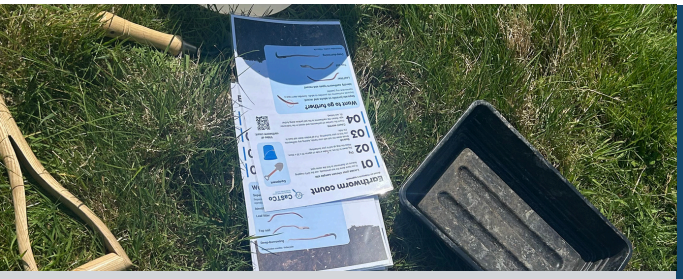
Co-design offers an opportunity to strengthen capacity among citizen scientists, supporting not only data collection but also wider learning, engagement, and empowerment. When participants are involved from the outset, projects can be better tailored to reflect local knowledge, interests, and capabilities.

Training should not be limited to technical protocols. Instead, it should extend to data interpretation and practical application, enabling participants to understand the significance of their contributions. Co-designed training, developed in dialogue with volunteers, can be more responsive to local contexts, increase accessibility, and enhance uptake.

Incorporating reflexive elements within training and implementation encourages participants to consider their role in shaping knowledge and its use. This fosters critical engagement with environmental issues and supports longer-term commitment.

Peer learning and horizontal knowledge exchange are also important. Regular opportunities for participants to share experiences help to build confidence, reinforce learning, and support the emergence of local leadership. Ongoing support, feedback loops, and visible responsiveness to volunteer input are essential to maintaining trust and momentum.

Finally, capacity-building outcomes such as **increased skills, confidence, and community engagement** should be recognised and reported alongside data outputs, helping to embed a more holistic understanding of citizen science impact (see also p25).



What does the wider literature say?

Capacity-building must be embedded throughout, rather than provided only at the outset. This includes reflexive training, peer learning, resources in accessible language (including native language(s)), and opportunities to shape research tools and interpret results (Heinisch, 2021; Robinson et al., 2018).

Case study: Soil SmARt co-designed training

The training that took place as part of CaSTCo's Soil SmARt citizen science was as co-designed as possible. Volunteers were asked to indicate what they'd like to be provided with, both in terms of information and monitoring equipment. We were also reflexive with the level of detail involved.

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The duration and timing of the training was also decided by the farmers, who preferred a half day morning session between farming activities.

It was good fun, wasn't it, during the training day. I think you could sort of use it as a bit of a thing for farmers getting together and a bit of a mental health thing of actually people chilling, asking questions, learning together.
– Mid-project evaluation interview, Soil SmARt citizen interview (SS2)

Principle 11 | Recognise and Reward Participation

Value citizens as core team members. Acknowledge their contributions through visible recognition, ongoing communication, and, where appropriate, opportunities for shared authorship or leadership.

Many citizen scientists find volunteering inherently rewarding, often motivated by the experience of contributing itself. However, it is essential that these efforts are recognised, as their time, skills, and resources should be valued (Pateman et al., 2021; Robinson et al., 2018). Recognition should be meaningful and linked to genuine influence over project decisions, avoiding tokenistic gestures that undermine trust (Arnstein, 1969; Shirk et al., 2012). Volunteers are more likely to remain engaged when they see their work lead to tangible outcomes and when findings are communicated back in accessible ways (Walz et al., 2021; Ceccaroni et al., 2021). This may include professional guidance, feedback, and visible action from intended data users, as well as showing how data has informed decisions or driven change. Providing regular, engaging updates through newsletters or events (Citizen Science Association, 2018) and inviting participants to wider opportunities such as workshops or conferences can further strengthen engagement.

Valuing contributions can also take formal forms such as authorship or group co-authorship on outputs (Kullenberg & Wiksell, 2020; Sauermann et al., 2020; Aristeidou et al., 2021), public celebration through awards, showcases, or media features, and offering skill development and leadership opportunities. These practices align with Self-Determination Theory by supporting autonomy, competence, and relatedness, which are key to sustaining motivation (Haivas et al., 2013; Aristeidou et al., 2022). Informal gestures, including social gatherings or shared refreshments, can build community bonds and reinforce intrinsic motivation (ECSA, 2015).
Transparent reporting on how contributions are used, and involving participants in deciding how they wish to be recognised, helps ensure rewards are relevant, equitable, and non-tokenistic.

Citizens are more likely to commit to supporting co-design and decision making if they feel valued - rewarding participation has a role here.

"We know the pollution's there but we need professional guidance and and people to look at those sorts of issues and it will be very rewarding if the Environment Agency were able to do that and we're to have the funding to do that. That's the sort of thing that would make citizen science more rewarding - because it's very rewarding now because of the incredible bunch of people that I work with, so talented in so many ways...but that would be the icing on the cake." (CS22)

Valuing citizens' contributions: steering committee membership

Including citizens in high-level decision making, if they wish, can help value participation. One citizen described a CaSTCo project where the steering group had volunteer representatives, which was well received as it gave those interested in the strategic side an opportunity to be involved and feel valued:

"*We have a project steering group that's made-up of ourselves and then also some of the other key partners. But we unlike a lot of the demos, very early on, we got some volunteer reps on to that group. So we've got two volunteer reps that are actually involved with the monitoring, and they sit within the project steering group and they make sure that when we're doing project planning that the volunteers are at the heart of everything, we're doing and if we're discussing anything they can keep asking 'Oh, but what about what about the volunteers? How's this going to work for them and what are they going to get out of it?". (CS24)*

Principle 11 | Recognise and Reward Participation (continued)

River Guardians' Perspectives on recognition: need for considering the role of individuals within 'tiered' projects

CaSTCo's tiered framework for citizen science envisages participation ranging from Tier 0 (mass participation, observational) through to Tier 3 (High precision testing) (Figure 4). River Guardians, by design, sits within Tier 1, where volunteers are trained to collect data using high-density indicative methods and standardised protocols. This "average tier" placement, however, obscures the diversity of experiences and aspirations within the project.

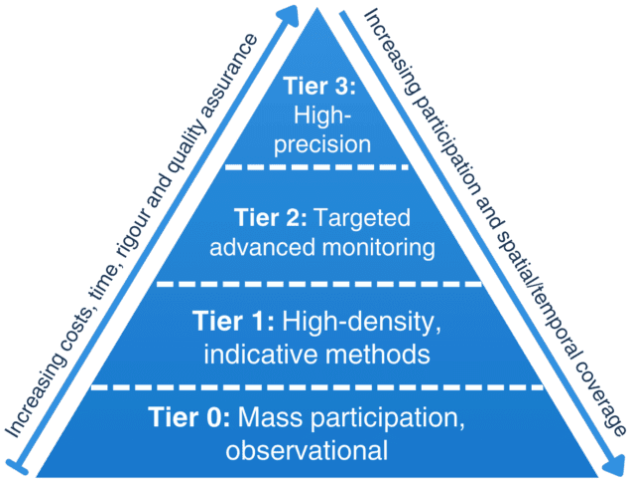

Figure 4: CaSTCo's tiered framework for citizen science monitoring. This is useful for gaining a broad understanding of the likely outcomes of projects but perhaps doesn't fully recognise individual citizens' contributions within such projects.

Our data show that while many volunteers were content with routine sampling and did not seek ownership of the data, describing themselves as "just the gatherers", others pushed the boundaries of Tier 1. Some compiled their own scorecards and shared them with parish councils, others used results in reports for local groups, and a few lobbied MPs and the Environment Agency directly. One group fundraised to purchase e-coli monitoring equipment, edging into Tier 2 specialisation. These examples highlight that individuals often ascend the tiers in pursuit of greater competence, autonomy, and influence.

The current tier-based model (above) struggles to capture this flexibility of individual trajectories. Volunteers who devoted many hours each week to water quality issues, built local alliances, and acted as advocates are still classified as Tier 1 because their activities did not include "advanced monitoring." This rigid focus on method risks discounting the political, communicative, and relational work that volunteers undertake, which are equally vital to the citizen science ecosystem.

The consequences of this mismatch are clear. Some volunteers expressed frustration with River Guardians' organisation and decision-making, particularly when their ambitions for deeper involvement were blocked. Others sought fulfilment by participating in multiple citizen science projects, thereby broadening their skillset (competence), networks (relatedness), and opportunities for influence (autonomy).
From a Self-Determination Theory perspective, the absence of structured pathways beyond Tier 1 risks thwarting motivation for those who desire greater ownership or impact.

These findings suggest the need to rethink tiered models of participation for enabling individual citizens to feel valued and recognised. Rather than a linear ladder defined narrowly by monitoring sophistication, participation could be understood as a spectrum spanning technical, communicative, and advocacy roles. Recognition should reflect not only how volunteers collect data, but also how they mobilise it, whether through education, community engagement, or policy influence. This more flexible approach would better capture the realities of River Guardians, where contribution cannot be reduced to sampling techniques alone, but encompasses the wider civic and political actions volunteers undertake.

Principle 11 | Recognise and Reward Participation (continued)

Good practice in recognising and rewarding participation means going beyond monitoring roles to value the civic, relational, and advocacy work that volunteers also undertake.

Good practice checklist

- Recognise that individual citizens may play different roles within projects. For example, a 'tier 1' project may include volunteers who go above and beyond and fit better into 'tier 2'.
- Show how data has informed decisions or led to change.
- Provide regular updates through engaging formats, such as newsletters or events.
- Offer professional feedback and guidance from data users.
- Involve participants in conferences, workshops, or related opportunities.
- Publicly celebrate contributions through awards, showcases, or media.
- Provide skill development, leadership opportunities, and authorship where appropriate.
- Organise informal social activities to strengthen community bonds.
- Cover expenses or provide resources to ensure equitable participation.
- Involve volunteers in deciding how they wish to be recognised.

By broadening recognition to include technical, communicative, and advocacy roles, projects can sustain motivation and create more inclusive pathways for participation.

Principle 12 | Support Continuity and Legacy

For projects that demand longer-term or ongoing monitoring, design for longer-term impact by embedding the project in local networks, identifying continuation pathways, and communicating what will happen post-project. Consider how citizens might stay engaged beyond the initial scope.

Planning for longevity: For co-designed citizen science to achieve lasting impact, there must be a clear plan for continuation beyond initial funding. This includes exploring whether and how the project could become self-sustaining, whether through community ownership, integration into institutional structures, or continued support from funding bodies. Early planning for legacy can help avoid a common problem in citizen science: the loss of momentum once formal project timelines or budgets end.

Funding and sustainability: Limited or short-term funding is a key barrier to establishing a sustainable legacy. Without secure pathways for ongoing support, projects risk losing trained volunteers, established networks, and accumulated goodwill. In turn, this can undermine trust and make it harder to engage participants in future initiatives.

Avoiding the risk of disengagement: When continuation plans are absent or unclear, there is a risk that participants will perceive their time and contributions as undervalued. This can have knock-on effects on willingness to participate in future projects. Addressing legacy proactively helps ensure that the benefits of co-designed citizen science—both social and environmental—are maintained well beyond the project's funded lifetime.

What does the wider literature say?

Long-term engagement can be achieved by ensuring citizens themselves benefit in some way from taking part - whether through learning, a sense of 'giving back', or any of the other motivations identified in our complementary report (Chivers et al, 2025).

The literature suggests that maintaining accessible platforms, building networks among participants, and embedding the work within existing community structures (Rollason et al., 2018). This is particularly effective when citizens feel that their efforts will continue to matter after the project's formal end. There are also several studies linking the need to foster citizen motivation for encouraging ongoing engagement (e.g., August et al, 2019; Domroese et al, 2017).

Case Study: CaSTCo

The CaSTCo programme provides an example of the importance of early and strategic legacy planning. While interviewed participants valued the opportunity to contribute and saw potential for long-term benefits, yet there were challenges in securing a clear continuation pathway. Feedback indicated that legacy planning could have been embedded earlier and more strategically, with clearer oversight of how the programme would transition beyond its funded period. While the programme achieved significant engagement and learning, the experience highlights a crucial lesson for future projects: to ensure that long-term planning, governance, and sustainability strategies are in place from the outset. Doing so can help preserve the trust, skills, and enthusiasm generated, and avoid a loss of engagement in subsequent initiatives.

06 Discussion and conclusions

This report has set out a series of principles to guide the co-design of future citizen science projects, by drawing on evidence from CaSTCo case studies, interviews with citizen scientists, scientists, and stakeholders, and the wider literature.

Co-design, when embedded across the project lifecycle, can make citizen science more relevant, trusted, and resilient. It enables projects to combine scientific robustness with local relevance, while recognising the value of diverse expertise and lived experience.

Shifting from top-down models to shared decision-making requires unlearning and relearning established approaches, supported by skilled facilitation, relationship building, and an openness to participant-led ideas. Meaningful involvement strengthens ownership and motivation, helping to secure both high-quality data and broader social and environmental benefits.

Recognition and reward emerged as central to sustaining engagement. Valuing participants' labour, particularly in economically constrained contexts (Pateman et al., 2021; Robinson et al., 2018), supports equity and retention. Recognition must go beyond token gestures, with tangible evidence that contributions have influenced decisions or informed change. Professional feedback, regular updates, invitations to wider opportunities, authorship, skills development, and informal community-building activities can all help to maintain trust and motivation.

Planning for continuation and legacy is essential. Without clear pathways for sustaining activity, there is a risk of losing skills, networks, and trust built during the project. The CaSTCo programme illustrates the importance of early, strategic planning for governance, funding continuity, and potential self-sustaining models. While it achieved strong engagement and learning outcomes, feedback suggested that earlier and more formalised legacy planning would have supported longer-term impact.

Overall, co-design should be seen as an ongoing process rather than a single stage. When supported by adequate resources, early legacy planning, and genuine recognition of contributions, it can help citizen science deliver enduring benefits for both science and society. The principles set out in this report are intended to provide a practical foundation for designing future projects that are scientifically robust, socially inclusive, and capable of sustaining impact beyond their funded lifespan.

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Appendix 1: Soil SmARt co-design outcomes

Table: Soil health tests chosen by farming citizens for testing, based on their needs and interests.

Purpose of test	Citizen-led tests	Agronomist-gathered tests	Potential scientific tests
Soil structure	Visual examination of soil structure (VESS)	Visual examination of soil structure (VESS)	Soil profile analysis (VESS also accepted)
Soil texture	Soil texture jar test	Soil textural classification	Laboratory-based soil texture (exact sand, silt, and clay measurements)
Soil aggregate stability	Slake tests	N/A	Rainfall simulator; soil polysaccharides; root imagery
Soil infiltration	Infiltration (pipe method)	Infiltration test	Guelph infiltrometer or double ring
Soil fauna	Earthworm counts	Earthworm counts	Environmental eDNA Nematodes
Soil biological activity	Solvita respiration test (/ 'soil my undies')	Respiration tests	Soil enzyme profiling Microbial activity Catabolic profiling (MicroResp)
Soil chemical properties	pH, NPK (in-field methods)	pH, NPK, Mg, organic matter (LOI), Dumas (total carbon, total N)	Dumas (OM), Nitrates, ammonia, Olsen P (bioavailable P)
'Other' soil physical properties	N/A	Bulk density, EC scanning	Soil moisture release curves (SMRC)

Figure 5. Example instruction sheet provided to citizens based on their preferences for soil health testing.

Access all Soil SmARt instruction sheets here:

https://wsrt.org.uk/about/our-projects/soil-smart