Scaling Participation: A Genealogical, Relational, and Reparative Analysis of Standardisation in Marine Citizen Science

Rethinking Quality and the Governmental Paradox Between Past, Present, and Future
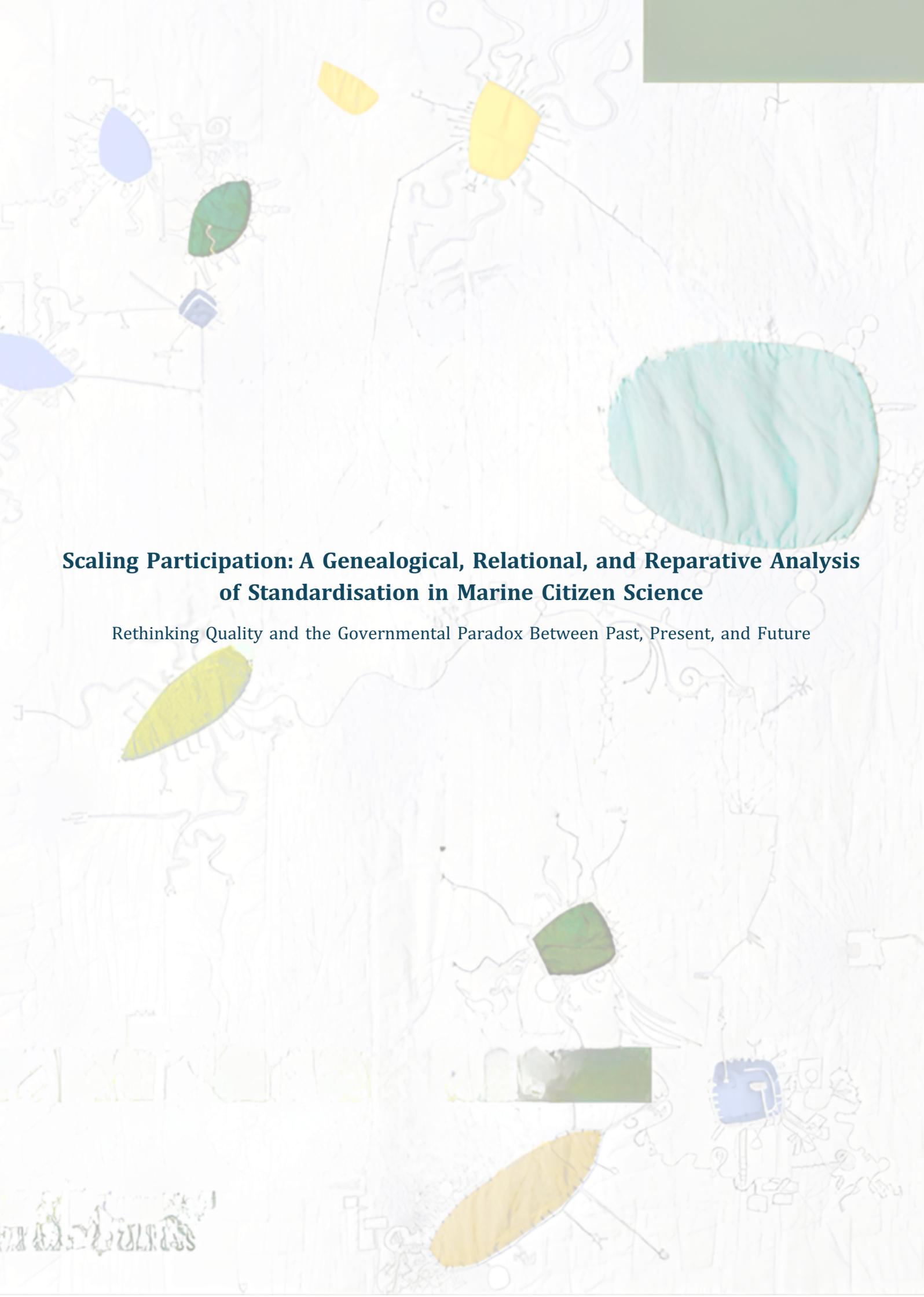
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Acknowledgements

Abstract

This thesis examines how expert communities in marine citizen science construct and navigates a governmental paradox: the standards and validation practices that make citizen-generated observations usable for science and policy can also restrict what counts as legitimate knowledge and participation. Using the European OBAMA-NEXT initiative as a primary case, the thesis approaches standardisation as a socio-technical process rather than a purely technical one, tracing how protocols, categories, and platform design shape whose observations can circulate and under what conditions.

The analysis combines a genealogical sensibility with relational thinking about scale-making and a reparative orientation toward design. It draws on interviews with experts, thematic workshops, archival material, and participant observation to examine the discourses and decisions through which citizen's participation is configured in expert forums. The thesis follows how inclusion is built into professional infrastructures that distribute authority and labour while presenting themselves as neutral measures of data quality.

The findings show that current arrangements often position citizens primarily as data providers rather than knowledge producers, even as democratisation rhetorics frame citizen science as epistemically and politically transformative. Comparability is achieved through practical 'cuts' that stabilise categories and reduce variability, enabling data to travel across scales while narrowing epistemic possibilities. To move beyond critique, the thesis proposes a Trinary System that replaces ladder-like participation models with three equally legitimate purposes. The proposal offers a way to widen what can count as meaningful participation without discarding the infrastructural need for comparability in marine environmental monitoring. The thesis concludes that the paradox is not a flaw to be solved once and for all, but a constitutive tension that can be handled more transparently and more inclusively through careful redesign of standards.

Keywords: Citizen Science; Standardisation; Data Validation; STS; Knowledge Production; Scale-making

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Abbreviations

CS	Citizen Science
ECSA	European Citizen Science Association
Environmental DNA	eDNA
MCS	Marine Citizen Science
Social sciences and humanities	SSH

1   Introduction

The relationship between scientific knowledge production and public participation has undergone profound transformations throughout history (Renn, 2015; Strasser et al., 2018a; Vetter, 2011). From the gentleman naturalists of the Victorian era to contemporary digital platforms enabling mass collaboration, the boundaries between professional scientists and engaged citizens have been continually negotiated, contested, and redrawn (Alberti, 2001; Allen, 2001; Lakhani & Panetta, 2007; Majchrzak & Malhotra, 2020). Today, as we face complex global challenges that exceed traditional institutional capacities, citizen science (CS) has become both a practical response and a site of inquiry into scientific authority, expertise, and democratic participation in knowledge making (Fraisl et al., 2020; Frickel et al., 2010; Herzog & Lepenies, 2022; Sauermann et al., 2020).

CS is, by its very nature, an interdisciplinary subject of research (Crain et al., 2014; Tauginienė et al., 2020). This is reflected in a fluid conceptual landscape in which multiple, context-dependent definitions and terminological variants coexist (Eitzel et al., 2017; Haklay et al., 2021). Despite this ambivalence, we adopt a working definition informed by the European Citizen Science Association (ECSA)'s principle of CS and key scholarly accounts: CS is an *open, inclusive* form of *collaboration* in which members of the public *voluntarily engage* in one or more stages of the scientific process together with professional scientists, thereby contributing new knowledge across a wide range of disciplines (European Citizen Science Association [ECSA], 2015; Haklay et al., 2021). Yet the language of openness and inclusion can also obscure how participation is made possible through protocols, standards, and infrastructures that format what counts as a legitimate contribution. Accordingly, this thesis does not make claims about citizens' lived experiences. Instead, it investigates citizen agency as configured in experts' imagination and enacted through the socio-technical arrangement experts design, debate, and stabilise.

The central question animating this research is to: **How do expert communities in marine citizen science construct, perpetuate, and potentially transform the conditions under which CS is made more (or less) inclusive?** We approach this question through the OBAMA-NEXT project as a primary case study. As a marine citizen science (MCS) initiative, OBAMA-NEXT provides a rich site for examining how tensions between scientific credibility and public participation are configured in practice. Empirically, we designed a mix method that draws primarily on archive and literature analysis, semi-structured interviews and workshops with scientists and other expert stakeholders across epistemological traditions, including positivist natural sciences and interpretive and critical social sciences and humanities (SSH). Our focus is thus on expert forums where 'good data', 'quality', and 'participation' are negotiated, rather than on the experiences of participating citizens.

Theoretically, we combine three complementary lenses to analyse how participation is configured. First, a genealogical sensibility helps trace how contemporary ideals of participation and standardisation inherit earlier ways of positioning the within scientific knowledge production (Albert et al., 2021; Strasser et al., 2018a; Tauginienė et al., 2020). Second, drawing on relational anthropology, we treat inclusion as relational and scale-making which is produced through connections and separations between actors, devices, protocols, and classificatory schemes. Third,

inspired by reparative reading, we attend not only to how standards can reproduce exclusions, but also to the practical openings through which expert communities might reconfigure participation without collapsing scientific comparability. This leads us to treat inclusion as potentially multiple, since different ontologies of what CS is and what data is for imply different and sometimes incommensurable ways that citizen agency is configured in experts' imagination and governed in practice.

Through this investigation, we aim to move beyond celebrations of CS as inherently democratising and instead develop a nuanced understanding of how power operates in and through expert-led arrangements.

2   Field of Inquiry: Locating the Object in Techno-Anthropology

This thesis is positioned within the interdisciplinary field that studies the intersection of technology and anthropology, namely Techno-Anthropology. Techno-Anthropology is an academic and professional practice committed to tracing how technical arrangements and human worlds co-produce one another and to using those insights to help build more robust and socially responsible technologies (Børsen et al., 2025; Elgaard Jensen, 2013). In this light, a master's thesis in this field must make a substantial contribution to both the research area and to ongoing societal challenges (Aalborg University, n.d.). The project is anchored its inquiry in the expanding landscape of CS, with a particular focus on the standardisation practices that govern how volunteer observations become authoritative data.

Standardisation as technology is a well-established argument in Science and Technology Studies (STS). Technological standards are norms or specifications that govern the development, implementation, and use of technologies (Bi et al., 2020), emerging from processes that integrate technical and organisational resources and are shaped by economic, political, and infrastructural contexts (Liang et al., 2023; Markard & Truffer, 2008). In STS, standards are not seen as neutral or merely technical; they are material-semiotic apparatuses that stabilise certain forms of action while making others difficult or impossible (Bowker & Star, 1998; Latour, 1991). Bruno Latour's claim that "technology is society made durable" underscores how standards translate social relations into enduring configurations (Latour, 1990). Susan Leigh Star built on this by treating standards as the invisible workhorses of modern life, demonstrating that standards possess the key features of technological systems: they rely on installed bases, gain momentum over time, and become visible only when they break down (Star, 1999). Together with Geoffrey Bowker, she further showed how classification systems and standards co-produce social and scientific realities, arguing that these artefacts act technologically by shaping what can and cannot move through bureaucratic and scientific channel (Bowker & Star, 1998). As technical devices, they render the heterogeneous equivalent (Lampland & Star, 2009), and embody power by locking in formats and protocols, thus distributing privilege beyond their immediate domain (Bowker & Star, 1998; Winner, 1980).

Collectively, these well-presented STS arguments establish that standardisation is an active social-technical practice. This thesis focuses on the standardisation of knowledge production as its central object of study, viewing standards as simultaneously technical artefacts, organisational routines, and moral economies. In setting out to research MCS, it becomes necessary to situate the inquiry within the broader institutional and political contexts that shape how standardisation unfolds in practice.

3 Contextual Background of Empirical Domain

The dynamics of standard-setting and participatory technologies are embedded in transnational frameworks with the EU backing and funding CS projects, where principles as well as frameworks, have been formulated in order to operationalise CS (Ros & Oesterheld, 2025). One of the European Research Area priority actions, as defined in the Pact for Research and Innovation (R&I) in Europe (Council of the European Union, 2021), is active citizen engagement in science. Additionally, the Open Science Policy of the European Commission poses that the general public should possess the opportunity to make meaningful scientific contributions (Beereboom, 2021) with CS as one of its eight policy ambitions. These developments emphasise including CS data with FAIR data principles[1] (Hansen et al., 2021; Wilkinson et al., 2016) The European Citizen Science Associated (ECSA) launched in 2013 is a newer representation of the EU's backing of CS. While these policy frameworks set the overarching scene for CS support across Europe, practical implementation depends on concrete projects translating ideals of participation and standardisation into situated practices. The OBAMA-NEXT initiative provides one such example, illustrating how CS operates as a testing ground within the European research landscape.

3.1 The Case of OBAMA-NEXT – A European Marine Citizen Science Initiative

OBAMA-NEXT represents a marine science initiative where CS is a component of the project and was used in creating an innovative suite of tools designed to generate detailed, reliable, and contextually relevant information about marine ecosystems and their biodiversity. The project's approach involves merging technologies, such as remote sensing, environmental DNA (eDNA), cutting-edge optical equipment, and CS initiatives, with traditional marine monitoring methods. The idea is to enhance the ability to document eco-system functions and biodiversity with improved accuracy and finer spatial and temporal resolution (European Commission, 2025) while facilitating a collaborative process.

We were working on the OBAMA-NEXT project as research assistants and saw first-hand how the integration of the natural and SSH was central to the collaboration happening. With such innovative projects, challenges remain where OBAMA-NEXT serves as a concrete expression of the ambitions and tensions embedded within contemporary CS, demonstrating both the promise and fragility of interdisciplinary collaboration. Yet, while dynamics play out empirically, they also point to a deeper conceptual question: what kind of phenomenon is CS itself, and how do its diverse genealogies and epistemic foundations shape what it becomes in practice? To explore this, the following section turns to the conceptual background of CS, tracing how its multiple trajectories, from democratisation to data production, have established both opportunities and persistent frictions in the pursuit of participatory science.

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[1] FAIR principles entail Findability, Accessibility, Interoperability, and Reusability (Hansen et al., 2021).

4 Conceptual Background: What is the Problem?

CS has become increasingly visible across research fields(Kullenberg & Kasperowski, 2016; Vohland et al., 2021) and is often presented as fostering collaboration in inquiry (Scanlon & Papathoma, 2024). Vohland et al. (2021a) attribute this growth to rising recognition of citizen-generated data value and mutually reinforcing technological advances. The expansion of CS is also connected to pressures on universities to make research processes more transparent and publicly accountable, for instance through outreach or by demonstrating the value of public spending (Hecker, Haklay, et al., 2018; Vohland et al., 2021). Yet despite its prominence, CS remains difficult to define because its purposes, approaches, and contexts vary widely (Wiggins & Crowston, 2014).

4.1 Epistemological Origins and Interdisciplinary Tensions

The term "citizen science" is commonly traced to Alan Irwin (1995), who articulated CS in a sustainable development context as part of a broader democratisation of research. For Irwin, publics hold forms of expertise shaped outside formal institutions, which is grounded in everyday experience, that are crucial to producing knowledge, especially on environmental issues. In parallel, an epistemological strand associated with Bonney (1996) positioned CS as a means to extend professional research capacity while also improving public understanding of science through participation (Hecker & Taddicken, 2022). Many projects combine these aims, but scientific knowledge production remains a central objective across much CS practice (Chandler et al., 2017; Devictor et al., 2010; Theobald et al., 2015; Sauermann et al., 2020).

CS developed as both a participatory method and an emergent field, making interdisciplinarity a defining condition (Crain et al., 2014; Tauginienė et al., 2020). Projects typically blend expert-nonexpert collaboration across engagement, education, and data work (Jordan et al., 2015), producing conceptual pluralism with multiple definitions and terminologies (Eitzel et al., 2017; Haklay et al., 2021). Tauginienė et al. (2020) Tauginienė et al. (2020) note that SSH contributions may be rendered less visible by narrow understandings privileging natural-scientific methods. This interdisciplinary tension foregrounds epistemological questions about which forms of knowledge count, how they are validated, and whose contributions are legible within CS infrastructure.

4.2 Citizen Science and its Employed Use within Marine Sciences

Across CS portfolios, natural sciences dominate (Göbel et al., 2022). In Europe more than 80 percent of current CS projects are related to life and natural sciences while a mere 11% are rooted in the SSH (Hecker et al., 2018). MSC remains comparatively underrepresented although it shows growing trend (Garcia-Soto et al., 2021; Sandahl & Tøttrup, 2020; Thiel et al., 2014), partly because marine sampling often demands access, transport, and safety capacities (e.g., diving certification) (Roy et al., 2012). However, barriers also arise from institutional and infrastructural features, including limited openness and weak data management. Wehn et al. (2025, p. 1006)describe MCS as "far from fully open", and Davis et al. (2023) report that a minority of MCS initiatives make data fully or partially open compared to CS initiatives more broadly. This points to a practical need

to strengthen FAIR-aligned practices, but also to a deeper question: how do marine science infrastructures define legitimacy and participation, and to what extent do they accommodate diverse ways of knowing?

4.3   Data Quality, Standardisation, and the Governmental Paradox

Scepticism toward CS (also within marine science) often centres on data quality, volunteer expertise, and the reliability of citizen-generated knowledge (Alabri & Hunter, 2010; Hunter et al., 2013; Cigliano et al., 2015; Kosmala et al., 2016). Concerns that policy might rest on unreliable data have historically constrained uptake and funding (Cohn, 2008; Dickinson et al., 2010, 2012; Wiggins, 2012). Yet evidence suggests that volunteer-generated datasets can reach quality comparable to professional data, particularly when projects use standardised protocols, training, calibrated tools, and structured validation (Kosmala et al., 2016). ICT, sensor technologies, and platforms further support quality through feedback loops, traceability, and error detection (Leach et al., 2020). In short, the problem is increasingly less whether citizens *can* produce reliable data, and more under what conditions their contributions are accepted and able to circulate.

However, the same mechanisms that make citizen data acceptable can also function as governance devices. Validation hierarchies, sampling standards, quality filters, and expert curation produce commensurability that renders heterogeneous observations comparable across space and time (Bowker & Star, 1998). But in doing so they set boundaries around what can be observed, how is the format of handling, and whose knowledge wight heavier. Expert communities (scientists, data stewards, platform designers, and sometimes advanced citizen scientists) design protocols, set thresholds, and maintain infrastructures that both enable and delimit citizen agency (Kasperowski & Kullenberg, 2018; McAteer & Flannery, 2022). Yet these arrangements are often viewed as technical necessities rather than political distributions of authority (Gottinger et al., 2023; Ottinger, 2010). This motivates a term we coin as the governmental paradox of CS: inclusion is granted under conditions that can erase epistemic difference, because participation is channelled through standards that privilege certain forms of knowledge and exclude others that do not fit required formats, taxonomies, or timings.

5   Problem Statement, Research Questions, and Design of the Thesis

Across CS literature, three recurring problem clusters hinge on expert decision-making. First, participation inequality reflects not only citizens' capacities but expert choices about training, thresholds, and workflows that privilege already resourced publics (Land-Zandstra et al., 2021; Pateman et al., 2021). Second, extraction persists when volunteers contribute time and knowledge while experts retain control over framing, methods, analysis, and authorship (Cooper et al., 2014, 2021; Göbel et al., 2022; Resnik et al., 2015). Third, credibility concerns often prompt stricter validation regimes that boost reliability but narrow participation to preformatted, low-autonomy tasks (Aceves-Bueno et al., 2017; Alabri & Hunter, 2010; Kosmala et al., 2016). Altogether, these dynamics show CS as a field where scientific authority can reassert itself unless the politics of

infrastructures and standards are made explicit (Irwin, 1995; Strasser et al., 2018b) (Irwin, 1995; Strasser et al., 2018).

An expert-centred approach is needed because standards are socio-technical and political: they fix classifications, units, and workflows that distribute privilege beyond their technical scope (Lampland & Star, 2009; Latour, 1990; Star, 1999). A core limitation in current MCS scholarship is that standardisation is rarely analysed as expert work unfolding over time. Participation, credibility, and platform governance are often examined in isolation, leaving underexplored (a) how 'neutral' requirements were historically assembled, (b) how they are operationalised today, and (c) where feasible redesign levers might lie. Addressing this limitation requires a temporal analysis through the lens of expert forums, leading to the central problem statement:

How do expert communities in marine citizen science construct, perpetuate, and potentially transform the governmental paradox whereby standardisation mechanisms designed to enable participation simultaneously constrain possibilities across past formations, present operations, and future alternativities?

To answer this complicated problem statement, we break it to several concrete research questions, that can answer the problem statement together:

RQ 1: How did experts construct and navigate the governmental paradox of CS whereby incompatible epistemological traditions became strategically assembled into a functional apparatus?

Part 1 reconstructs two trajectories documented in the literature: (1) a social-science genealogy that produces the citizen as interlocutor and participatory subject, and (2) a natural-science genealogy that produces the observer as a disciplined sensor (Foucault, 1972, 1977, 1980, 1982; Irwin, 1995; Strathern, 2000; Wynne, 1992, 1992). Using archival/literature analysis and expert interviews, the aim is to denaturalise what now appears technical by tracing the conjunctures that made MCS assemblages possible.

RQ 2: How are contemporary decisions by expert communities produced the connections that enable contributions and agency to circulate across projects and scales?

Part 2 maps decision points (protocols, validation, infrastructures, and governance) and, through interviews and workshops, identifies the actionable levers where experts recognise within existing institutional and technical constraints. The purpose is to render the present architecture of authority and possibility legible enough that Part 3 can develop reparative, feasible configurations.

RQ 3: How do expert forums design the conditions that let CS data travel across scales, and how could these designs be adjusted to be more inclusive?

Part 3 synthesises candidate reconfigurations articulated in existing research, workshops and interviews, translating critiques into practicable modifications that broaden participation while retaining the integration that standards enable (Jönsson et al., 2024).

Taken together, genealogy clarifies what has been inherited (RQ1); mechanism mapping clarifies what is being done and by whom (RQ2); and reparative specification clarifies how change might realistically be attempted from within existing infrastructures (RQ3). The thesis aims to make the standardisation–participation paradox in MCS empirically legible and, in doing so, to outline credible routes for transforming it without forfeiting the comparability on which marine data infrastructures depend.

6 A Tripartite Theoretical Framework: Towards a Relational-Reparative Model of Knowledge

The following theoretical section establishes a tripartite analytical framework for examining the governmental paradox of CS: that participation is promoted as democratic inclusion while being conditioned through standardisation and validation. We approach standard as socio-technical arrangements that organise power and access. The framework is structured temporally. A Foucauldian genealogy is used to diagnose how contemporary CS configuration emerge from historically contingent dispositifs that produce particular subject positions. A Strathernian lens then analyses how these arrangements operate in the present through partial connections, scale-making practices, and cuts. Finally, a Sedgwickian reparative orientation supports a weak, future-facing engagement with what can be reworked inside existing infrastructures. It proposes not a solution to the paradox, but a way of holding multiple goods in view and specifying feasible alternatives. Together, the three perspectives allow us to move from historical diagnosis, through relational analysis of scaling, toward a reparative reconfiguration of standardisation in MCS.

6.1 Genealogy of Standard Knowledge Production

Our genealogical strategy follows Foucault's insistence that what now appears as neutral is the residue of past power structures, "a history of the present", that renders contingency visible (Foucault, 1977, p. 31). Drawing explicitly from Nietzsche's critique of metaphysical origins, Foucault's genealogy rejects the "metaphysics of the ideal origin" (Ursprung) which refer to the search for pristine essences or foundational moments of origin (Foucault, 1977, p. 140; Nietzsche, 1887). Instead, genealogy attends to Nietzschean term "Entstehung" (emergence) and "Herkunft" (descent), tracing the contingent, and often accidental beginnings of practices that later claim timeless authority (Foucault, 1977, p. 142-145). As Foucault explains: "Genealogy does not pretend to go back in time to restore an unbroken continuity… On the contrary, to follow the complex course of descent is to maintain passing events in their proper dispersion" (Foucault, 1977, p. 146).

This lens exposes how data collection standards operate as mechanisms of subjectification, producing the expert scientist and the lay contributor as distinct subject positions with CS platforms, even when participatory in intent, inherit and reproduce historical formations that position citizens as data providers, or receiver of knowledge, rather than knowledge producers (Foucault, 1982, p. 781).

6.1.1 Discourse, Dispositif & Subjectification

Genealogy shows that every apparently neutral method is embedded in a discourse, "practices that systematically form the objects of which they speak" (Foucault, 1972, p. 49), which constitutes what can appear as legitimate knowledge. Central to this is Foucault's dispositif (apparatus): (Foucault, 1980, p. 194). The dispositif is precisely the network that connects these heterogeneous elements (Foucault, 1980, p. 195). Within the domain of the natural sciences, modern research

ideals like controlled observation crystallized when physical dispositifs (measurements) aligned with social dispositifs (learned societies, referee systems, laboratory architecture) (Daston & Galison, 2007).

The process of subjectification is how individuals are constituted as subjects within these dispositifs, also proves crucial for understanding CS hierarchies. Citizens participating in scientific projects are "subject to someone else by control and dependence and tied to [their] own identity by conscience or self-knowledge" (Foucault, 1982, p. 781): subjected to standardised protocols while internalising their identity as amateur or volunteer contributors.

6.1.2   Constructing Regimes of Truth Within and Between Scientific Disciplines

We apply this conceptual apparatus to two formative arenas of CS, natural science (represented by marine biologists) and social science (represented by anthropologists and political scientists), to show how each discipline built its own standards for collecting, coding, and validating observations through, a Foucauldian term, disciplinary power: a form of power that disciplines the body, regularises populations, and normalises (Foucault, 1977). This disciplinary power both grounds and vehicles regimes of truth: "the types of discourse which it accepts and makes function as true; the mechanisms and instances which enable one to distinguish true and false statements" (Foucault, 1980, p. 130). Each scientific discipline establishes its regime of truth through dispositifs that determine who can speak, from what positions, and with what authority. These regimes are maintained through procedures of exclusion (Foucault, 1970), particularly the will to truth and subjectification that masks power's operations. When CS platforms require standardised taxonomies, photographic evidence, or training modules, they deploy these procedures as productive constraints that generate scientifically legible data while producing the trained volunteer as a subject position.

6.1.3   Genealogy as a Diagnostic Tool

Genealogy contributes three insights for CS analysis. First, it reveals the contingency of standardised methods as artifacts of historical disputes over credibility, not timeless best practices, showing that expert/amateur, professional/volunteer, scientist/citizen distinctions are contingent products of struggles over epistemic authority (Dean, 1994; Foucault, 1977a, p. 154). Second, it highlights material-discursive coupling: how power operates through apparently neutral technical standards like data formats, validation procedures, and quality controls as governance mechanisms (Burchell et al., 1991; Rabinow, 1986). Finally, it provides vocabulary for analysing partial exclusion beyond suppression narratives, showing how instruments and discourses co-constitute each other to stabilise epistemic authority (Foucault, 1980; Rose, 1999). By tracing the contingent history of MCS in Europe, genealogy denaturalises immutable interface constraints. It identifies why dispositifs are reconfigured now-a-days. Yet genealogy cannot fully account for how these formations operate as living, negotiated practices in contemporary CS platforms, which is why we require a complementary framework.

6.2 Partial Connections and the Problem of Scale: A Strathernian Analysis of Citizen Science

Upon establishing how standardisation and validation emerged as historical dispositifs through genealogical analysis, we turn to their contemporary enactment as relational configurations. To complement this historical diagnosis, the Strathernian framework foregrounds the relational and scalar dimensions of knowledge production to illuminate how participation and authority are continuously negotiated rather than historically fixed; how CS and contributions thereof create relationships that are neither fully integrated nor fully separated with scale-making practices demonstrating how scalar transformations determine whose knowledge achieves scientific significance; and network cutting exposes how projects create boundaries even while claiming openness.

6.2.1 Merographic Connections Introduces Wholes, Partial Connections Separates Those Wholes

Merographic connections in Strathern' terms refers to parts connecting to wholes without constituting a totality and they provide essential vocabulary for analysing how CS assembles knowledge (Strathern, 1992). In merographic thinking, "parts are not simply fragments of wholes but have their own completeness" while simultaneously being "partial with respect to something else" (Strathern, 1992, p. 73), creating the concept of wholes. This double character of completeness and partiality perfectly captures the CS contribution: When thousands of citizens contribute observations to a biodiversity monitoring platform, each contribution maintains "its own integral character" while being "part of something that exceeds it" (Strathern, 1992, p. 76).

If wholes can be represented by each observation (a full account of what was seen) yet partial with respect to scientific knowledge production, then partial connections refer to relationships where entities can be related without being identical, linked without forming a unified whole (Strathern, 2004). The concept of partial connections also illuminates how different epistemological frameworks coexist without merging: When citizens use standardised protocols to record observations, they connect to scientific practice but only partially: their observations must travel through transformative processes of validation, aggregation, and interpretation before achieving scientific status. The connection is real but incomplete; citizens are simultaneously inside and outside the scientific enterprise. Yet these partial connections are productive precisely because they are partial (Strathern, 2004).

6.2.2 The Problem of Scale and Scale-Making Practices

Strathern's insight that scale is not a neutral measure, but an effect of specific practices fundamentally reframes how we understand CS hierarchies. Scale is not just a matter of size but of the organisational and conceptual work required to make different entities commensurable — the process through which things must be translated into a shared metric or placed on a common scale to reveal their comparative value (Latour, 2000; Strathern, 2004). In CS, scale-making

practices determine whose knowledge can be scaled (up) to scientific significance and whose remains trapped at the level local observation or amateur interest.

Consider how a single bird sighting by a citizen observer must undergo scalar transformation to become scientific data. The observation begins at what we might call the 'individual scale': a person seeing a bird at a particular moment. Through entry into a platform like eBird, it is rescaled to become part of a dataset, but this rescaling is not automatic. It requires standardisation (using accepted taxonomic names), verification (often through photographic evidence or expert review), and aggregation (combining with thousands of other observations). Each of these operations is scale-making work (Strathern, 1996, 2004); active practices that create the appearance of seamless scaling while actually performing complex transformations.

The scale problem emerges particularly when CS projects scale local knowledge for global environmental governance, where aggregating local fishing communities' observations into marine biodiversity databases gains coverage and sample size but loses contextual richness, relational understanding, and place-based meaning—the embedded, specific, relational qualities that also make such knowledge valuable.

6.2.3   Cutting the Network: Boundaries and Exclusions

The last concept we borrowed from Strathern is that of cutting the network, which provides inspirational insight into how CS projects create boundaries even while claiming openness (Strathern, 1996). Drawing on her contribution to actor-network theory (ANT), Strathern argues that "networks are infinite; they have to be cut to be made visible" (Strathern, 1996, p. 523). Every CS project performs such cuts, deciding where participation begins and ends, what counts as contribution, and who qualifies as a citizen scientist. When a marine monitoring project requires smartphones for data submission, it cuts the network to exclude those without digital access. When a project mandates English-language reporting, it performs a linguistic cut. When protocols require scientific nomenclature, they cut out vernacular ways of knowing. As Strathern emphasises: "The very enablement of a network... has the effect of cutting the network... One makes a cut or break in the flow... [which] creates a limit" (Strathern, 1996, p. 523). Standardisation operates as "a cut that enables connection" (Strathern, 1996, p. 527)—by excluding non-standard contributions, it allows remaining data to connect within scientific networks. Yet this seemingly necessary cutting also performs exclusions that may contradict CS' democratic aspirations.

6.2.4   Implications for Citizen Science Analysis

Strathern's theoretical framework reveals CS as a space of fundamental tensions between connection and separation, scaling and specificity, transparency and complexity. Her concepts provide analytical tools that avoid both romantic celebration of citizen participation and cynical dismissal of its possibilities. Instead, they offer a way of mapping the complex, non-binary relationships that constitute CS. Moreover, the Strathernian analysis demonstrates that CS' challenges are not failures to be overcome but constitutive features of how different knowledge systems create partial connections. The impossibility of full integration between citizen and

scientific knowledge is not a problem to be solved but a generative tension that produces new forms of knowledge, new types of subjects, and new modes of relating. By applying Strathern's concepts to CS, we can move beyond asking whether these projects democratise science (they partially do) or whether citizen data is as good as professional data (it is differently good). Instead, we can examine how scale-making practices create hierarchies, how merographic connections assemble knowledge, and how network cuts perform inclusions and exclusions. This analytical framework allows us to understand CS not as a failed attempt at full participation but as a space of partial connections that generates its own forms of knowledge, power, and possibility.

6.3 From Paranoid Exposure to Reparative Possibility: A Sedgwickian Framework for Reimagining Citizen Science

Sedgwick's distinction between paranoid and reparative reading offers a transformative framework for moving beyond critique to generative possibilities in CS. Sedgwick (2013) identifies paranoid reading as the dominant mode of critical theory, seeking to expose hidden structures of domination before they can cause harm (Sedgwick, 2003). While a genealogical analysis engaged in such paranoid reading, by revealing how standardisation operates as governance and how validation procedures encode hierarchies, Sedgwick warns that paranoia has become "less a diagnosis than a prescription" in critical scholarship (Sedgwick 2003, p. 125). The paranoid position places its entire "faith in exposure" (Sedgwick, 2003, p. 130).

In CS studies, this manifests as endless exposure of how projects fail their democratic promises, how participation masks exploitation, how inclusion conceals deeper exclusions. While such critiques are necessary, as our Foucauldian genealogy will demonstrate, Sedgwick observes that paranoid reading operates through 'strong theory' reducing complexity to anticipated structures: exposing power structures does not automatically undermine them (Sedgwick, 2003, p. 127). The paranoid imperative to expose produces is paradoxical: the assumption that revealing power structures automatically undermines them (Sedgwick, 2003). CS is an example where exposing how standardisation excludes vernacular knowledge has not prevented platforms from proliferating such standards.

6.3.1 Reparative Reading as Design Orientation

Reparative reading emerges not as a replacement for paranoid criticism but as a different position from which to begin (Sedgwick, 2003). Where paranoid reading anticipates negative affect and positions itself defensively against expected harms, reparative reading remains open to surprise, seeks positive affect, and asks what might be assembled from part-objects rather than demanding systematic wholes. This orientation proves particularly generative for reimagining CS because it allows us to recognise partial goods without requiring perfect solutions, as Strathern's relational anthropology suggests. The reparative framework offers an alternative to more emancipatory approaches like critical constructivism, commonly reflected in CS literature (Kimura & Kinchy, 2016; Ottinger, 2010). In contrast, the reparative position is characterised by "weak theory": not weak in the sense of inadequate, but in its refusal to extend a single overarching logic to every

situation (Sedgwick, 2003, p. 134). In CS, this means examining how participants create meaning, pleasure, and agency even within constraining frameworks, not to excuse those constraints but to identify resources for transformation. Thus, Sedgwick's attention to affect reveals dimensions of CS that paranoid reading overlooks. The reparative framework helps us understand forms of action that neither completely resist nor wholly capitulate to dominant structures. When citizens collect data, they are neither fully autonomous knowledge producers nor completely subjected data collectors, but something more interesting: agents driven by a "reparative impulse" to "assemble and confer plenitude on an object" from the fragments they encounter (Sedgwick, 2003, p. 149). For CS, this suggests moving beyond revealing what projects are not (truly democratic, fully inclusive) to assembling what they might become.

These three theoretical frameworks together create what Deleuze & Guattari (1987) call a "rhizomatic structure": multiple entry points, no single root, various paths of connection. Foucault reveals historical constraints, Strathern maps contemporary relations, and Sedgwick opens generative possibilities. This multiplicity is strategic, not eclectic, recognising that different aspects of CS require different analytical tools to imagine and build CS that repairs rather than reproduces citizen subordination. This tripartite framework frames the analysis itself: genealogy excavates the historical conditions that made current CS possible (Part 1), Strathern maps its contemporary relational configurations (Part 2), and Sedgwick orients us toward reparative futures (Part 3).

7   Methodology

The form and content of this study have been shaped by methodological decisions concerning empirical data collection and analysis. This section delineates these decisions in detail, employing a multi-method approach to elucidate the dynamics of CS and data standardisation as socio-technical processes, encompassing data infrastructures and epistemological tensions between natural and social sciences. Access was granted to data from the OBAMA-NEXT project, including a literature review synthesising approximately 200 peer-reviewed and grey literature sources on marine CS engagement and data practices, one group interview and three thematic workshops. This was supplemented by primary empirical materials consisting of four semi-structured interviews with several experts across disciplines, secondary empirical data in the form of archive and literature reading and limited participant observation during a field visit. The section further accounts for the use of deductive coding guided by the theory of Foucauldian genealogical -, Strathernian relational -, and Sedgwickian reparative frameworks followed by recruitment of interviewees, employed transcription tools, and our reflections related to ethical considerations and positionalities in relation to this research.

7.1   Interviews

We gained insight into the field by conducting semi-structured interviews to allows for a level of flexibility for clarification (Berg & Lune, 2004; Bryman, 2016; Gideon, 2012). Interviews are described "as a conversation with a purpose" (Lune & Berg, 2017, p. 65), typically face-to-face (Gideon, 2012), although our interviews took place online. Questions were were formulated based on the overall research question and sub-questions albeit kept simple and easy to understand to avoid any misunderstandings (See Interview Guides in Appendices I & II).

A group interview (Appendix III) was conducted as part of the OBAMA-NEXT project. The interview guide (Appendix I) was initially designed by another TAN-student along with Guodong and subsequently reviewed and refined by professors and co-workers from AAU to ensure its relevance and clarity. The process of recording, transcription, and subsequent analysis of the interview data was undertaken by one of the authors together with the other TAN-student affiliated with the OBAMA-NEXT project. In addition to this interview, four expert interviews were fully organised, including managing the organisational aspects, recording, transcribing, and in-depth analysing the interviews, which served to supplement the primary research and inform this thesis further with professional insights.

7.1.1   Who was Interviewed?

The empirical data gathered from interviews was acquired from different scientists working with CS – both experts in the field as well as scientists that have experience working with or on CS. Interviews were conducted with five scientists, coming from different scientific disciplines in Denmark and Norway. The table below provides an overview of the interviews (See Table 1).

Contact to the different respondents was established through professional network through the OBAMA-NEXT project, including people from the field visit.

Expert(s)	Role/disciplinary field	Interview place	Interview type	Interview date	Duration of interview (in minutes)
Experts from Phenomer	Phenomer Interview	Microsoft Teams	Group	17/9/2024	92
A	Senior researcher in Ethics and Philosophy/Social Sciences at a Danish University	Microsoft Teams	Individual	21/7/2025	65
B	Senior researcher at NIVA in water resource management, climate change, citizen participation and cross-sectoral collaboration and innovation	Microsoft Teams	Individual	4/9/2025	59
C	Senior researcher at NIVA in molecular biology, ichthyology, taxonomy, marine biology, non-native species, population genetics, evolutionary relationships in fish, and environmental DNA (eDNA) /Natural Sciences	Microsoft Teams	Individual	4/9/2025	68
D	Senior researcher in Philosophy/Social Sciences at a Danish University	Microsoft Teams	Individual	4/9/2025	65

Table 1: Overview of Interview Respondents

For an in-depth understanding of specific perspectives related a CS project, a semi-structured interview with Phenomer was conducted as part of the OBAMA-NEXT project. In this interview, the creator and scientific leader of the long-running and impactful CS project, Phenomer, presented his work in an in-depth group interview with two current leading researchers within the Phenomer project (co-authors in Siano et al., 2020). This interview (Appendix III) pointed to

factors behind the project longevity (13 years) such as the funding models applied, the data quality protocols, and strategies for community retention. The interview's insights fed directly into the first thematic workshop discussion on whether and how to combine/integrate CS data with data collected via other techniques. In addition to this interview, we conducted the following interviews specifically for the purpose of this thesis (See *B* to *D* in Table 1), but our empirical data also went beyond interviews as we also draw on empirical data gathered from workshops.

7.2   Workshops

A series of workshops were hosted by Aalborg University (AAU) to facilitate stakeholder engagement and gather qualitative insights relevant to the OBAMA-NEXT project. Guodong was responsible for the recording, transcription, and analysis of the workshop data. A total number of 19 people participated in three workshops that were held in the period between October and December 2024. For the first workshop, 18 participants participated; 12 for the second and 10 for the third.

Workshops make up arrangements formed by a group of people who learn, gain new knowledge, collaboratively solve problems, or innovate within a specific domain. Additionally, workshops are designed to address a pre-defined purpose but remains unpredictable due to the inability to foresee dynamics of group members (Ørngreen & Levinsen, 2017). By bringing together contributors to OBAMA-NEXT tasks along with invited experts who held hands-on CS experience, three thematic online workshops were carried out. The workshops set out to investigate central issues in current CS practices, showcase illustrative case studies, and develop actionable recommendations for advancing MCS (See Table 2).

Theme	Workshop place	Workshop date	Duration of workshop (in minutes)
Workshop 1: Whether and how to combine/integrate CS data with data collected via other techniques.	Microsoft Teams	October 22, 2024	120
Workshop 2: How to promote CS in marine science beyond data collection and towards 'extreme' forms of CS including analysis and interpretation of data – with illustrative CS project cases from AMBER Barrier Tracker and the Syke's Citobs.	Microsoft Teams	November 25, 2024	120
Workshop 3: Scrutinise potential and challenges for benthic/pelagic CS, including possibilities, usability challenges and caveats in using CS data for observation, monitoring and mapping of biodiversity, species and habitats – with illustrative CS project cases from AMBER Barrier Tracker and the Syke's Citobs.	Microsoft Teams	December 11, 2024	120

Table 2: Overview of Workshops

7.3   OBAMA-NEXT Literature Review & Archive and Literature Reading

We draw on knowledge gathered through a literature review primarily carried out by colleagues at AAU and other researchers involved with the OBAMA-NEXT project to ground the study in existing research and practice (Deliverable 2.3) regarding the improvement of long-term engagement in MCS by identifying design principles, challenges, and enabling strategies. The literature review was based around 200 peer-reviewed articles and grey literature, which was obtained through focused searches in Scopus and academic journals in the marine field. The literature review was in accordance with the criteria of identifying who are the citizen scientists and what tasks they are engaged in CS projects/initiatives (Cenci et al., manuscript in preparation). This work is indirectly drawn upon as it enhanced our knowledge in the field of MCS.

Additionally, archive and literature reading has been used as secondary literature to uncover historical and theoretical underpinnings of knowledge production to genealogically trace concepts. Specifically, the analysis draws from SSH scholarly works by Foucault, Irwin (1995), (Wynne, 1992a, 1992b, 1992c), Jasanoff (2006, 2007), Shirk et al. (2012), and others on CS typologies, STS, and participation frameworks. Natural science literature covers historical trajectories like Shapin and Schaffer (1985), Daston and Galison (2007), and marine cases such as iNaturalist, Reef Life Survey, and eBird protocols. Discourse-analytic reading of these sources traces genealogical

assemblages, with policy documents (e.g., ECSA 2015 principles, UK frameworks post-2008) treated as textual formations rather than physical archives.

7.4   Process of Recruitment, Deductive Coding, Transcription Tool and AI

The process of recruiting experts for interviews was done through the OBAMA-NEXT project, where the interviewed experts had all previously contributed to the project. All interviews as well as workshops were conducted online, which meant that the interviews were automatically transcribed live using Microsoft Teams' a generative AI tool for transcription. AI was furthermore used for language – and grammar correction.

Upon transcription all interviews and workshops were coded deductively based on the themes of identified through the theoretical framework. This way, we relied on the theoretical framework to direct the codes to the data (Kristiansen, 2022). Deciding to use a deductive approach was rooted in our intention to systematically operationalise the established theoretical framework within a predefined codebook and to examine how these concepts manifested across the interview material. Using NVivo 14, we conducted deductive coding of the interview transcripts with a theory-driven codebook comprising Foucauldian genealogical (discourse, dispositif, subjectification, regimes of truth), Strathernian relational (partial connections, merographic relations, scale-making practices and network cutting), and Sedgwickian reparative (paranoid and reparative positioning) codes to organise the empirical data and more easily look up relevant parts when analysing.

7.5   Ethical Considerations

In line with Beauchamp & Childress (2001) principles of ethics, we provided understandable and thorough information of the research to participants to get informed verbal consent, given during the recorded interviews and workshops where they were also told that they could retract any statements and consent altogether at any point of time. Interviews were anonymised and given different names, e.g. "Expert A". Additionally, data were stored safely on AAU clouds. For the field visit to Risø, consent was given through the invitation sent to us to come and observe, obtained through gatekeepers who were part of the OBAMA-NEXT project, including especially two AAU professors.

The field visit at Risø allowed us to observe despite being there as part of the OBAMA-NEXT project. A limited field visit at Risø functioned as participant observation that helped sharpen the problem statement and research questions. We do not use observations from this visit as empirical evidence for the thesis analysis. This positionality requires ongoing reflexive attention to the ethical implications of conducting research within existing project contexts and relationships, recognising that participants' awareness and consent regarding the research focus evolved alongside our own involvement.

7.6   Positionality & Reflexivity

Our role as social scientists in this project becomes increasingly important to reflect on, especially given the epistemological context of studying the genealogies of science (Schwandt, 2015). Reflexivity prompts us to critically examine not only how our presence in the field may have influenced participants, but also how our preconceptions about scientific practice, collaboration, and knowledge production may have influenced our methodological choices and interpretations (Finlay, 2002; Ide & Beddoe, 2024). Furthermore, we are aware that our interpretations and analyses are shaped by our disciplinary training and personal trajectories.

Being outsiders to the technical specifics of CS positioned us simultaneously as informed observers and relative novices, which may have enabled us to notice assumptions or practices that are otherwise taken for granted by insiders. Additionally, integrating interviews with participants from different disciplinary backgrounds introduced necessary heterogeneity and challenged initial assumptions as well as own professional biases. This triangulation of data sources, combining interdisciplinary interviews, workshops, archive and literature readings and participant observation serve to enrich our analysis and provide a more nuanced account of the dynamics at play. In this context, the social science data we generate can be seen as a form of meta-data, data about data, providing interpretive layers that reveal the social dynamics, power relations, and cultural assumptions embedded in CS projects and practices. Contrastingly, natural science data, which in the case of this thesis, comes to be positioned as the comparable data, serves as the empirical foundation against which these social interpretations are framed. By juxtaposing natural science outputs with the social science meta-data, we can illuminate differences in epistemological orientations: between objective measurement and interpretive analysis, or between data as material evidence and data as socially constructed meaning. This comparative perspective underscores the complementary yet distinct contributions of the two disciplines in advancing a holistic understanding of CS and data standardisation processes, facilitating dialogue between different scientific traditions. But importantly, it highlights how this thesis came to be shaped the way it did; without an author that represents the natural sciences. Therefore, as we proceed, we want to emphasise that coming from a social science perspective, our methodological approach is generally rooted in subjectivist or constructivist traditions, in contrast to the more typical positivist stance found in natural sciences. Nevertheless, we acknowledge the persistent limitations of our interpretive scope and remain mindful that our understanding is situated, partial, and open to critical engagement by scholars from other epistemic traditions. Finally, our reflexive practice involves continuing dialogue not only between ourselves as researchers, but also with stakeholders across disciplines with the aim of achieving a critically engaged approach to the study of scientific knowledge production in the topic of CS and data standardisation.

8   State of the Arts

This section situates the thesis within contemporary debates in (M)CS by offering an analytical synthesis of how participation, credibility, and data legitimacy are currently framed in the literature. Rather than providing a neutral catalogue of studies, it reads the state of the art through the thesis' central concern: the tension between openness and standardisation. Organised in three movements, it begins by briefly recapping how the field commonly orders participation through definitions, typologies, and recurring debates about interdisciplinarity and data quality, establishing the minimum scaffolding needed for the analysis to follow. Second, it develops the analytical core by bringing literature on legitimacy, validation, and epistemic justice into closer conversation with CS practice. Here the focus is on the mechanisms through which inclusion and exclusion are produced through. Third, the chapter turns to emerging alternatives as a repertoire of reparative resources. It identifies orientations such as 'good enough' data, community validation, and plural knowledge systems that challenge dominant assumptions about quality, participation, and authority.

8.1   Definitions and Typologies in Citizen Science

With CS becoming increasingly popular in recent years (Kullenberg & Kasperowski, 2016; Vohland et al., 2021), the variety of definitions, terms and conceptualisations has resulted in a myriad of typologies of CS (Haklay et al., 2021). CS projects appear extremely diverse (Wiggins & Crowston, 2011) yet take form across a spectrum of participation (Shirk et al., 2012). The definitional plurality produces typologies that stabilise participation by distinguishing roles, tasks, and implied forms of expertise. At its most inclusive, CS democratises knowledge production and empowers communities to address issues relevant to their own lives, highlighting the value of local expertise and perspective (Jaeger et al., 2023). However, the involvement of citizens in scientific research often goes unrecognised, as they are rarely given the same accreditation as researchers themselves, thus either not listed as (co-)authors or mentioned in the methods or acknowledgements sections. In such instances, only the data they contributed was made visible (Cooper et al., 2014).

Haklay's (2013) ladder remains influential because it stabilises participation as a scale and is widely reused in evaluation and guidance material. His typology, initially introduced in 2012 and expanded in subsequent works (Haklay, 2012; Haklay, 2013), defines four levels of engagement: Level one is *Crowdsourcing* where citizens act primarily as sensors. Level two is *Distributed Intelligence* where citizens act as simple interpreters and level three is *Participatory Science* at which citizens partake in the objectives/issues/problem definition and/or data gathering. Level four is *Extreme CS* and involves research that is primarily orchestrated by citizens, with scientists acting mainly as facilitators or supporters. Additionally, Haklay et al. (2021) proposed an expanded set of classification for categorising CS projects of which the most significant ones present as: (1) participants' level of cognitive engagement (beyond data gathering and collection); (2) required training and expertise for participants; and (3) data sharing conditions. These classificatory moves matter because they become shorthand for assessing credibility and 'appropriate' participation. (Haklay, 2013; 2018).

These classificatory moves matter because they become shorthand for assessing credibility and 'appropriate' participation (Haklay, 2013; 2018). While typologies have helped establish CS legitimacy, their evaluative use—and the hierarchical implications of arranging participation as a developmental sequence—will be examined critically in Part 3.

8.2   Criticism of Current Definitions and Typologies

Recent critiques argue that CS must expand what counts as 'science' and what kinds of public issues and knowledge practices it can host. This reframes participation not only as a method for producing data, but as a site where civic empowerment and epistemic standing are negotiated. Scholarly literature exists on CS as a democratic practice, typically discussed in terms of its practical and societal impacts, although there is also a deeper philosophical dimension that remains relatively underexplored (Jaeger et al., 2023). This dimension concerns the epistemology best suited to describe, analyse, and underpin democratic CS where the theory of knowledge becomes capable of capturing not only what is produced, but how it is produced. Jaeger et al. (2023) argue that humanity's current approach to scientific knowledge production is still shaped by outdated ideas that hinder progress. Jaeger et al. argue that dominant assumptions about how science produces knowledge limit innovation and democratic practice, motivating an epistemology that foregrounds process, plurality, and deliberation (Jaeger et al., 2023, p. 1).

In other words, contemporary science is hampered by an outdated, naive realist view that prioritises short-term efficiency over long-term productivity and innovation. As an alternative, Jaeger et al. (2023) propose an epistemology based on three pillars: (1) perspectival realism (i.e. offers an alternative to naive realism deemed relevant for the 21st century), (2) process philosophy within a framework of naturalistic epistemology that redirects attention from conceiving knowledge solely as the final output of scientific investigation toward an examination of the cognitive mechanisms and processes that underlie its generation, (3) deliberative practices, which centres around social interactions occurring among researchers, leading to reflections on how seeking consensus in science is not always desirable. They position CS as a practical arena for these aims, and stress the need for flexible, adaptive assessment methods able to register contextual and processual knowledge production.

These epistemological interventions also raise questions about how participation itself is evaluated in CS. If knowledge production is perspectival, processual, and deliberative rather than simply cumulative, then frameworks that measure CS quality primarily through depth of citizen involvement in predefined scientific tasks may miss alternative forms of epistemic contribution. This tension between pluralistic epistemologies and standardized evaluation criteria becomes a central concern for reimagining CS futures, as explored in Part 3.

8.3   Citizen Science at the Intersection of Interdisciplinary

Projects that connect (citizen) science – whether social or natural – with (citizen) humanities are interdisciplinary (Scanlon & Papathoma, 2024). Values achieved within those projects are based on being able to harness differences, e.g. approaches that are complimentary, which could be

theories, concepts, methods, data, tools or knowledge, can act as complimentary to one another in order to obtain a more holistic perspective on a phenomenon (Mitchell et al., 2017). A specific example of one such endeavour was the interdisciplinary CS project, Orchid Observer, which combined historical studies and natural science, which ultimately resulted in offering evidence of climate change (GrrlScientist, 2015; Robbirt et al., 2011). Additionally, it was the first CS project at such a scale that brought together online with field approaches as well as combined elements of citizen humanities with active science research (Heinisch et al., 2021). It managed to unite amateur-expert naturalists and outdoor nature enthusiasts with an online community for historical transcription. Collaborating with the expert orchid community and the Botanical Society of Britain and Ireland (BSBI), the project involved the public in study design and analysis. In connecting different knowledge areas like society, public engagement, education, communication and science (Wals et al., 2014), there have been reported advantageous for both scientists receiving feedback from citizens on the contributions and impact they have on wider public (Bonney et al., 2016; Freitag et al., 2016; Van Vliet et al., 2014). Meanwhile, citizens obtain a deeper insight into the processes within scientific communities through the immediate communication with scientists. The interdisciplinarity of CS shapes the production and validation of knowledge, which also means it can bring epistemological questions to the surface, because working across disciplines forces participants to confront different ways of knowing and producing knowledge.

8.4   Data Quality Issues

Scepticism is frequently associated with CS among professional scientists. One reason for the scepticism is that CS has yet to be acknowledged as a mainstream method in science (Riesch and Potter 2014; Theobald et al. 2015). Instead, CS has been categorised as a "questionable science" (Kosmala et al., 2016, p. 552). Professionals consider (unpaid) volunteers may not possess the necessary skills or are not committed enough to deliver a performance similar to that of those paid. Others have put forward concerns about ethics in establishing partnerships with volunteers (Resnik et al. 2015), including volunteers' motivations and reasons for participating as well as whether they are able to offer data of certain quality (Alabri & Hunter, 2010). These concerns are driven by a fear that policy based on scientific discoveries might ultimately be based on data that is unreliable as the data quality generated by volunteers – a long-time concern (Cohn 2008; Dickinson et al. 2010, 2012). Yet at the same time, CS is recognised for the wealth of knowledge it can produce as well as the scientific results and discoveries it can obtain(Bonney et al., 2014; Theobald et al., 2015). In fact, little scholarly work has been investigated around the accuracy and bias of data professionally generated within similar contexts as data produced by volunteers (Specht & Lewandowski, 2018). There can be substantial variation in the comparisons of data evaluated by and between several professionals (Earp et al., 2022). Meanwhile, Lukyanenko et al. (2016) argue that data quality in CS is a lot more than data accuracy.

Gabrys et al., (2016, p. 1) coin "just good enough data" based on work with northeastern Pennsylvania residents monitoring fracking-related air quality via inexpensive sensors, wind data, smell logs, flare videos, and symptom diaries. Regulatory bodies deem such data inadmissible because it lacks certified instruments, official protocols, and long-term stability required for U.S. compliance (Gabrys and Pritchard 2016). Residents' evidence of health effects, smells, flaring, or

particulates is dismissed as "not comparable" to official Air Quality Index values (Gabrys and Pritchard 2016, p. 10), blocking proof of immediate, intermittent, spatially specific harms (Gabrys and Pritchard 2016, pp. 6, 9–10). "Just good enough data" counters over-reliance on high-accuracy standards by assessing adequacy for demonstrating, interpreting, and politicising local exposures (Gabrys and Pritchard 2016, p. 6; 2021, p. 1): where good enough encapsulates sensitive enough to signal pollution events, legible to residents, and compelling to engage regulators (Gabrys and Pritchard 2016, pp. 6, 10).

In response, Gabrys and Pritchard (2016, p. 9) report the formulation of a standard through the design of a Citizen Sense kit, negotiating "good enough" standards without replicating state infrastructure: they co-develop low-cost, fenceline PM2.5 monitors for near-real-time resident readings cross-referenced with lived experience—discreet to avoid industry/neighbour reprisal risks from conspicuous gear. "Good enough" emerges via collective interpretation (comparing traces, wind data, smell/noise/body diaries to filter background vs. local spikes, forming vernacular protocols and institutional encounters (despite initial invalidation, datasets paired with state data spurred targeted official monitoring (Gabrys et al. 2016, p. 10). The standard came to bridge politics as well as method: participants often needed anonymity because there was a real fear of reprisal from neighbours and industry, and a bulky, official-looking instrument would have been both conspicuous and socially risky (Gabrys and Pritchard 2016).

8.5   Epistemic Justice

The tension between CS' democratic aspirations and its epistemic realities forms a critical fault line in contemporary scholarship. The ECSA's Ten Principles articulate an ideal where citizens occupy meaningful roles in producing "genuine science outcomes" through mutual feedback, recognition of all contributions, and public accessibility of results (Robinson et al., 2018, p. 29). Yet Herzog & Lepenies (2022, p. 490) question whether these expectations may be fundamentally misplaced questioning if CS is "just a pleasant hobby for highly educated people, or a handy way for scientists to gather unwieldy data?" They represent more recent scholarship that has begun to systematically apply epistemic injustice frameworks to CS contexts, revealing how seemingly neutral participation structures perpetuate knowledge hierarchies. Their analysis suggests that CS's democratic potential remains unrealised without deliberate attention to power dynamics in knowledge production. Traditional scientific hierarchies can systematically devalue non-expert knowledge claims, positioning participants as data providers rather than legitimate knowledge contributors (Herzog & Lepenies, 2022). This epistemic injustice in CS manifests through exclusion from research design, dismissal of contextual knowledge, and lack of recognition for contributions beyond data collection, particularly evident when projects restrict participant roles to observation while reserving interpretation and decision-making for professional scientists, ultimately arguing that true civic empowerment requires transforming CS from a one-way knowledge extraction process into a genuinely collaborative knowledge co-creation practice (Herzog & Lepenies, 2022; Liboiron, 2017; Ottinger, 2017).

Crucially, this injustice operates not merely through overt structural exclusion but through linguistic mechanisms that constitute scientific legitimacy. Building on Gieryn's (1999) concept of "boundary-work", contemporary scholarship demonstrates that language does not merely describe

reality but actively shapes what can be recognised as scientific knowledge (Eitzel et al., 2017). As Barad (2006) argues, epistemology, ontology, and ethics form an inseparable entanglement where "the way we come to know the world" directly shapes "our assumptions about what exists". When CS platforms employ standardised taxonomies that dismiss local ecological knowledge or require contributions to conform to professional scientific categories, they enact precisely this boundary-work, using language to demarcate what counts as valid science and who qualifies as a legitimate knowledge producer. The dismissal of contextual knowledge documented by Herzog & Lepenies (2022) is thus not incidental but emerges from epistemological frameworks embedded in linguistic practices that privilege quantifiable, decontextualised data over situated understanding. This shows how legitimacy is produced through boundary-making practices that decide what counts as 'science' and who counts as a knower.

8.6   Emerging Alternatives

The proliferation of CS initiatives over the past two decades has been accompanied by growing recognition that conventional approaches may inadvertently reproduce the very exclusions they purport to address (Cooper et al., 2021; Dawson, 2019; Paleco et al., 2021; Soleri et al., 2016). Scholars and practitioners increasingly seek alternative models to challenge what Ottinger (2017, p. 1) identifies as "scientific frameworks" where citizens serve primarily as data collectors; by addressing epistemic injustice (Herzog & Lepenies, 2022); labour extraction (Liboiron et al., 2018), and standardisation's marginalising effects (Kukutai & Taylor, 2016). These alternative approaches share a common recognition that democratising science requires not simply including more participants within existing structures, but fundamentally reimagining the relationships between citizens, scientists, and knowledge production itself.

A key alternative orientation is "just good enough data", which reframes quality as fit-for-purpose rather than regulatory comparability (see in Section 8.4). This orientation shifts attention from deficit models of citizen data toward negotiated thresholds of actionability. Similarly, iNaturalist's approach to 'research grade' observations, as analysed by Nugent (2018) replaces top-down validation with community consensus mechanisms where multiple identifications converge to establish data quality. This model recognises that knowledge validation can emerge through horizontal peer review rather than vertical expert authority. Thus, technical architecture of data platforms serves as a critical bridge between volunteer motivations and sustained participation by transforming abstract contributions into tangible value through feedback mechanisms and visualisation (Jennett et al., 2016; Nov et al., 2014). Making collected data accessible in multiple visualisation formats tailored to different user groups, from simple processed data displays for the general public to raw data access for researchers, ensures volunteers can engage with information at their preferred level of complexity, supporting both recreational enjoyment and personal development motivations (Jennett et al., 2016; Wiggins, 2012).

Designs that scaffold interpretation and make contribution pathways visible can support sustained participation while expanding epistemic roles beyond data submission (Rotman et al., 2012). These technical features collectively demonstrate respect for volunteers' time and intellectual contributions, transforming data platforms from mere collection tools into dynamic spaces where volunteers experience the scientific process firsthand, thereby strengthening their commitment to

the project's long-term success (Jennett et al., 2016; Rotman et al., 2012). However, citizen involvement in platform design remains limited, often due to resource constraints, leading to tools lacking relevant functionalities (Wiggins, 2012). When involvement is restricted to early "proof of concept" stages, volunteers may perceive their efforts as undervalued, decreasing motivation (Havlik & Schimak, 2014, p. 297).

8.6.1 Reparative Design and Remaining Gaps

Importantly, emerging from these alternatives are design principles that align with reparative rather than revolutionary transformation: Examples include models where scientists serve as technical supporters while communities control research directions (Dosemagen & Parker, 2018), and platforms accepting all observations without initial filters, allowing patterns to emerge from abundance (Aristeidou et al., 2021; Echeverria et al., 2021; Palma et al., 2024). (Aristeidou et al., 2021). Such approaches work with rather than against tensions between standardisation and inclusion, hinting at more reparative design. These alternative models point toward CS futures characterised by horizontal validation, multiple knowledge systems, sovereignty over inclusion, and support over standardisation. Yet significant gaps remain as few projects provide systematic frameworks for implementation; theoretical foundations for why alternatives work remain underdeveloped; and critically, no model fully addresses the temporal dimension of standardisation - allowing open initial collection followed by collaborative discovery of useful standardisations for different purposes.

Ultimately, the state-of-the-art shows that debates about participation and data quality are also debates about legitimacy. Emerging alternatives point to different validation arrangements, yet they rarely explain how standards become stabilised historically or how they might be reconfigured over time. This gap motivates the genealogical analysis in Part 1, which traces how contemporary configurations of participation and standardisation became thinkable, actionable, and institutionally durable.

9 Part 1: The Past
A Genealogical Analysis & Diagnosis

"…world is not the accomplice of our knowledge; there is no prediscursive providence which disposes the world in our favor. We must conceive discourse as a violence which we do to things, or in any case as a practice which we impose on them; and it is in this practice that the events of discourse find the principle of their regularity"

Michel Foucault, *The Order of Discourse* (1970, p. 67).

This first part of the analysis employs Foucauldian genealogy to examine how contemporary CS emerges not from a single origin but through a governmental articulation, a strategic arrangement whereby heterogeneous elements from distinct genealogies become assembled into a new governmental dispositif (Foucault, 1980). We trace how social sciences produced the 'citizen' as critical interlocutor and stress on 'participation' as key democratic practice, while natural sciences produced the 'observer' as disciplined sensor. We argue, the last 1990s STS and social science development, and later the 2008 financial crisis created conditions of possibility—those historical circumstances that make certain formations thinkable and practicable (Foucault, 1970)—for these incompatible subjects to undergo strategic convergence within the governmental rationality of austerity and pushed the 2010s CS bloom; this post-2008 convergence produces the paradoxical figure of the citizen scientist as a governed subject who must simultaneously embody critical participation and disciplined observation, and the CS as a method of highlighting its cost-effectiveness and cover-range while showing its flaw of producing scientific enough contributions.

9.1 Producing the Citizen as Critical Subject: The SSH Trajectory

We approach 'citizen' and 'participation' not as transparent descriptors but as historically layered terms that do world-making work. A discourse-analytic reading of SSH writing on CS shows how these two terms stabilise particular subject positions and value languages that make some forms of public action legible and others peripheral. A genealogical sensibility helps to track how, over three decades, the same words have been re-keyed: citizen oscillates between a liberal-civic bearer of duties, a community-anchored actor, a sensing instrument, and an affected subject; participation oscillates between outreach, contribution, deliberation, and co-production (ECSA, 2015; Irwin, 1995; Shirk et al., 2012; Vohland et al., 2021; Wiggins & Crowston, 2014).

The critical break with a deficit view of publics is well rehearsed in STS, from Wynne's (1992) of Cumbrian sheep farmers to Irwin's *Citizen Science*, which dislodged the assumption that lay publics mainly need more information and instead foregrounded situated knowers whose judgements turn on trust, identity, and institutional responsiveness. Jasanoff's work on civic epistemologies pushes the point further, showing that what counts as credible public reasoning varies across polities so the figure of "the citizen" is never generic, always co-produced with national and institutional styles of public knowledge-making (Jasanoff, 2006, 2007). As the field codified itself, typologies and frameworks sedimented those shifts. Arnstein's (1969) ladder, relaunched in CS venues through spectra and typologies, performs a double act: it criticises tokenism while also pre-distributing roles before any empirical encounter. Shirk et al. (2012) and Haklay (2013) distinguish

"contributory", "collaborative", and "co-created" projects; but the verbs that attach to the citizen across these genres—collect, classify, validate, occasionally co-design—quietly script the horizon of acceptable action. Participation, in this literature, becomes a programmatic term that confers legitimacy on projects yet often anchors legitimacy in designers' decisions about who may set categories, interpret at scale, or author claims (Vohland et al., 2021; Wiggins & Crowston, 2014) The point is not that typologies are cynical but rather, they are speech acts that stage the subject positions they purport to merely describe.

Terminological debates make this staging visible. Eitzel et al. (2017) show how labels, for instance citizen, community, volunteer, human sensor, Indigenous/local knowledge holder, all carry consequences. "Citizen" can silently exclude non-nationals; "community" foregrounds place and social ties; "human sensor" instrumentalises the subject for data regimes; "Indigenous/local knowledge" signals plural epistemic authorities while risking relegation to "context" rather than method. Land-Zandstra et al. (2021) remind us that even apparently neutral recruitment and training materials position participants as learners or co-professionals, shaping the kinds of contributions that can be recognised. At the heart of these textual formations lie infrastructures and standards where (Bowker & Star, 1998) and Star & Ruhleder (1996) teach us to see classification systems, schemas, and forms as moral-technical devices. In CS discourse, quality assurance/quality control (QA/QC) talk performs real epistemic work while simultaneously relocating authority to judge away from participants (Daston & Galison, 2007; Porter, 1995). The value languages of rigor and objectivity are not simply gatekeeping rhetoric; they are attempts to make heterogeneous contributions travel. Yet they also normalise a figure of the citizen as a disciplined observer whose credibility is conditional on conformity with procedures designed elsewhere. This is why the same text may endorse participation expansively while tying legitimate claims to strict metric regimes. The contradiction is not a mistake; it is the condition of circulation in academic and policy arenas. SSH discourse on CS often foregrounds how citizens may scrutinise and deliberate, but training modules, dashboards, and project glossaries typically remain professional prerogatives.

Foucault's analytics of subjectivation helps name the process: through dispositifs that interlink statements, institutions, and devices, people are addressed as particular kinds of subjects, including volunteer, witness, co-designer, and invited to inhabit these roles (Foucault, 1982). This reading could be misheard as a lament, but SSH offers a different moral: translation is constitutive. There is no access to "the citizen" outside of genres, standards, and institutions that make utterances portable; what (Latour, 1987) calls the chains of reference that enable claims to travel. Yet anchoring the terms, then, yields a precise conclusion. In CS discourse as read through SSH, citizen is the name for a subject produced at the intersection of value languages (empowerment, inclusion), devices (taxonomies, sensors, dashboards), and genres (typologies, methods sections, ethics statements). Participation is the name for a set of authorised movements within that staged space, from noticing and documenting, to deliberating and co-designing, to, less often, setting categories and authoring claims. Across the corpus, citizen and participation are indeed placed at the rhetorical centre; yet, in practice, SSH methods, standards, and publication norms translate citizens' voices in ways that render the citizen-subject in texts co-authored, negotiated, and sometimes lost. That loss is not simply failure; it is the cost of making knowledge travel.

The SSH genealogy thus produced a specific subject: the citizen as bearer of situated knowledge, capable of contesting framings, demanding accountability, and co-producing research agendas. This subject emerges through dispositifs of participation, dialogue, and reflexivity. Yet this genealogy remained largely disconnected from natural science practice, which was simultaneously producing an entirely different subject through its own distinct dispositif. The conditions of possibility for their governmental articulation had not yet emerged.

9.2 Producing the Observer as Disciplined Sensor: The Natural Science Trajectory

While SSH scholars were dismantling the deficit model and theorising co-production, natural sciences were refining their own technologies for incorporating non-professional observers, but through an entirely different genealogical trajectory. Where SSH sought citizens who could speak back, natural sciences sought observers who could see correctly. These parallel genealogies would remain incommensurable until austerity created the governmental imperative for their strategic convergence.

A genealogy of modern science begins with the joint making of credible facts and credible witnesses. In the Boyle–Hobbes settlement, experimental 'matters of fact' were stabilised by repeatable procedures and the testimony of disciplined gentlemen within new spaces of publicity; the laboratory and the learned society co-produced what counted as scientific and who could count as a scientific witness (Shapin & Schaffer, 1985). Through the nineteenth century, objectivity took institutional form as a moral virtue inscribed in instruments and selves: first 'mechanical objectivity,' disciplining the hand and eye to defer to the machine; then 'trained judgment,' disciplining expert sight to recognise patterns and discard noise (Daston & Galison, 2007). Quantification promised fairness by displacing discretion into forms, measures, and audits (Porter, 1995). When this formation meets the sea, its stakes intensify. Oceans are not ready-made objects; they become knowable through globally distributed chains of reference such as sensors, taxonomies, simple protocol repositories that knit local traces into worldwide claims (Edwards, 2010; Latour, 1987). Marine science thus exemplifies the modern scientific wager: comparability first, then truth. Participation arrives at this already settled grammar of comparability. It is here that citizens take shape not as a free interlocutor but as a subject position offered by the regime. For instance, trained observer, compliant data producer. Read together with Foucault, these histories show a power/knowledge formation in which regimes of truth crystallise as ensembles of discourses, devices, and venues (Foucault, 1980). Crucially, such regimes do not merely constrain subjects; they produce them. Through processes of subjectivation, people learn to recognise themselves in the roles a dispositif offers, gaining agency through techniques that also govern them (Foucault, 1982; Rose, 1999).

Discourse is the hinge. Marine observing communities' script the ocean as a set of variables that must be watched to know and govern it; they script the good knower as one who observes, documents, validates, uploads. Seen this way, familiar marine cases become legible as moments where truth and subject are co-made. Consider coastal naturalists on iNaturalist who learn to seek "Research Grade" so their sightings can flow to biodiversity aggregators; they acquire taxonomic

habits, geolocation discipline so to be counted as a 'good' encounter is now what can travel (cf. (Eitzel et al., 2017; Hacking, 2002). None of these actors are coerced. They are enrolled by a discourse that binds truth to comparability and ties recognition to conformity, which is a regime in which citizen is the name of the one who consents to be formatted. The citizen appears in this rhetoric as one who wants to be disciplined, who desires the status of "usable" and therefore submits to the protocols that confer it. This is a politics of willing subjection: not domination from above, but government of conduct through moralised languages of rigor, responsibility, and stewardship (Rose, 1999; Strathern, 2000). The subjectivation here is double. First, citizens learn to see the ocean in the categories the dispositif sustains; second, they learn to speak in the grammar that render them audible. The regime of truth is effective precisely because it binds seeing and speaking to belonging.

Marine scientists genuinely invite publics in; they do so within a regime of truth that ties credibility to comparability. The resulting power relation is neither crude domination nor pure emancipation. It is a willing subjection: citizens shape themselves into compliant observers so their voices may circulate as 'scientific'. What appears in publications and repositories is therefore a co-produced subject; a centered rhetorically, rendered scientific through adherence to inherited grammars, and thus trained/subjected to marine science's infrastructure. The natural science genealogy thus produced its own subject: the disciplined observer whose credibility derives from conformity to standardised protocols. To understand why these genealogies remained separate requires examining how natural sciences produced their own distinct subject: not the critical citizen but the disciplined observer. This genealogy, emerging through 19th-century practices of specimen collection and systematic observation, created dispositifs that could incorporate non-professionals only through specific technologies of subjectification.

9.3 Genealogy of MCS in Europe: Austerity Assemblage of Democratising Knowledge and Scientific Standards

The genealogy of European CS reveals two moments of governmental articulation. The first, emerging from 1990s SSH critique, created discursive space for citizens as knowledge-makers rather than knowledge-deficient publics, but remained largely a critical project that legitimised lay knowledge without the apparatus to operationalise it. The 2008 financial crisis transformed these conditions of possibility, posing a governmental and scientific problem: how to extend observational capacity under austerity while preserving democratic legitimacy. The crisis acted not as an origin but as a contingent accelerator, aligning audit cultures with existing participatory repertoires and infrastructures, and enabling the articulation of two previously incommensurable genealogies: SSH traditions of critical participation and natural science traditions of standardised observation.

This convergence operates through technologies of government that shape conduct by structuring the possible field of action (Foucault, 1982). Citizens are not compelled to participate; rather, participation appears simultaneously as democratic agency and as disciplined contribution to state observation, while marine scientists speak to citizen motivation and rights and SSH scholars engage with data standards, blurring earlier disciplinary divides. CS in Europe thus began not as a

technique but as SSH critique. Building on 1980s and 1990s work in SSK, feminist epistemology, and critiques of the deficit model, Irwin's formulation reimagined citizens as partners in defining problems and making knowledge, yet left unresolved natural scientists' metrological worries about bias, calibration, and metadata. Before 2008, CS remained largely a normative project: funding instruments, evaluation metrics, and weak infrastructures made participation admirable but not auditable, and thus difficult to scale within state knowledge systems. The 2010s boom of European CS is therefore better read as a political assemblage forged in the wake of the 2008 crisis than as a simple by-product of cheaper technologies. Austerity reshaped who could know on behalf of the state and under what conditions their knowledge would count; in the UK, deep cuts to environmental budgets were followed by new CS guidelines and QA/QC frameworks that rendered volunteer observations contractable, comparable, and defensible in policy files (Roy et al., 2012; Tweddle et al., 2012).

A similar reconfiguration appears in Finland. The Finnish Environment Institute (Syke) concluded in its State of the Environment in Finland 2013 that the financial crisis since 2008 had tangibly affected environmental action, slowing policy processes while also changing pressures on the environment (Bach et al., 2020; Putkuri et al., 2013). Against that backdrop Syke launched Järviwiki (Lakewiki) in 2011, explicitly described as cooperation "between authorities and citizens", standardising lay observations through categories and metadata so they could travel into official monitoring (Osbeck et al., 2013). Järviwiki's significance is political: the phones and lakes were presented before; what was new was the governmentalisation of lay observation and the re-assembled of the elements, and an interface that choreographed citizens as reliable auxiliaries to the state.

At the EU level, the Citizen Observatories line in FP7/H2020 operationalised this settlement. Projects such as WeSenseIt (2012–2016) were designed with and for decision-makers in the UK, Netherlands, and Italy, validating how citizen reports and low-cost sensing could be accepted by authorities managing floods and water (CORDIS, 2019; EUROPABON, n.d.). In parallel, the Commission's move to Responsible Research and Innovation (RRI) and Open Science reframed participation as a funding-aligned virtue, making publics into governable partners whose engagement, data sharing, and transparency could be required and audited (European Commission, n.d.; Von Schomberg, 2013). The ECSA crystallised the apparatus. Founded in 2014, it issued the Ten Principles of Citizen Science in 2015, which read simultaneously as disciplinary code and compliance standard: defining tasks, stressing mutual benefit, assuring data quality, acknowledging contributions, and managing legal–ethical issues (ECSA, 2015; Robinson et al., 2018). This is precisely the kind of power/knowledge realignment that converts a social ideal into an administrative normal.

Ultimately, the bloom of CS after 2008 was more political than philanthropic. Austerity did not found CS, it accelerated an articulation already in motion. Austerity reallocated resources and authority, and European policy reframed participation as a condition for funding and legitimacy. Associations, standards, and platforms emerged not because technology finally made CS possible, but because the state needed new relays of observation and new ways to hold them accountable, within a tighter budget on scientific observation. The result is the 2010s settlement: CS as a technology of government, capable of extending the state's sensory field while make the budget looks good (Bach et al., 2020; CORDIS, 2019; Department for Environment, Food and Rural

Affairs, 2010; ECSA 2019; Garcia-Soto, van der Meeren, Busch, Delany, Domegan, Gorsky, et al., 2017; Putkuri et al., 2013; Roy et al., 2012; Tweddle et al., 2012).

9.4 Living the Articulation: Dispositif, Paradoxes, and Double Discourse in Contemporary Practice

With the brief genealogy of CS, we undertake a Foucauldian discourse analysis of how CS is assembled in contemporary European marine and aquatic monitoring. Rather than treating CS as a neutral method, the analysis traces how talk and practice make particular subject positions, rules, and truth-conditions possible. We read interviews and workshop materials to surface the statements through which democratising ambitions and austerity-era rationalities are braided into an auditable apparatus. It is also foregrounding the conflictual co-presence of two historical trajectories: the democratising project that casts citizens as co-producers of knowledge, and the austerity-era reallocation of resources that mobilises citizens as cost-efficient extensions of the state's sensory apparatus. The materials show how subjects called citizens are simultaneously interpellated as motivated collaborators and as governable, auditable operators within standardised regimes. These tensions are not incidental; they are constitutive of the apparatus, and they invite later theorisation through Marilyn Strathern's notion of partial connections.

9.4.1 Validation and Infrastructured Participation

Where the trajectories of democratisation and austerity intersect, regimes of quality and validation reassert expert authority even as they depend on lay labour. In the HAB case, this dispositif becomes visible through the language of filtering and validation:

> "We have some filtering process on the data. We make some validation… it's still in the database but with a specific status—Non-validated data" (Interview, Phenomer).

Validation here is not simply technical but performative: a categorical and procedural gate that preserves traceability while restricting evidential authority to expert procedures. The database keeps the citizen visible but not authoritative. Only later is this asymmetry named explicitly:

> "The CS approach is [that] the data produced by citizens cannot be directly exploited by researchers… we still need expert evaluation and quality checks… volunteer citizen collaboration may contribute 'only'… to sample collection" (Workshop 1).

The act of retaining "non-validated" data thus both acknowledges lay contribution and circumscribes it. Citizens are mobilised to look, collect, and send, but these gestures become knowledge only when processed through expert pipelines. The very design that opens knowledge production outward simultaneously consolidates the authority of those entitled to certify it. This tension surfaces again in the rhetoric of coverage and complementarity. CS is praised as an expanded sensorium:

> "61% of the Phenomer observations were not detected by routine phytoplankton monitoring systems" (Workshop 1).

The proof of value thus binds CS to institutional grammars; what citizens see matters because it augments the state's reach. This logic under austerity, extending capacity through unpaid perception, also necessitates standardisation. Instruments and interfaces translate openness into auditability. Drones and apps, celebrated for accessibility, are enclosed by calibration and protocol:

> "These persons with the drones need to have a protocol to follow… then you can calibrate your RGB images… [there also has to be a] pipeline to get all these images— that's also a big task" (Workshop 1).

—yet the value of this excess is articulated within institutional grammar. The citizen's gaze matters because it extends the state's reach; what improvement means is defined by existing monitoring frames. The citizen becomes indispensable precisely as a substitute for absent resources, and derivative insofar as seeing counts only when it fits expert modalities of verification. Cheapness alone does not democratise data; protocols make it commensurable with institutional quality regimes. Even legality becomes disciplinary: "you need a license… it's an online certificate or course," to operate drones under EU rules (Workshop 1). In this configuration, the "citizen" is both a mobilised observer and a credentialed operator—participatory yet governed.

9.4.2 Motivation, Quality, and Graduated Citizenship

The discourse of motivation sutures this arrangement. On one hand, it invokes reciprocity and proximity—feedback, plain-language identifications, and "shorter distance between scientists and… people" (Workshop 1). On the other, it maintains throughput in an under-resourced observatory. Ease is valorised as infrastructure:

> "The success of Phenomer actually was the fact that it was easy… everybody can take a picture… the picture is immediately sent to us" (Workshop 1).

Motivation, then, is cultivated affectively but channelled procedurally. Citizens are inspired to care, but also calibrated to act – where, when, and how institutions require. Care legitimates discipline: the moral language of inclusion obscures how participation is made governable, and how responsibility for error shifts from systemic constraint to "unsystematic" or "untrained" contributors. This dynamic becomes explicit in talk around quality, where the pluralisation of quality, whether temporal, spatial, instrumental, transfers instability from institutions to devices or markets:

> "Same technology… but because they don't standardise the same way… we don't get the same output" (Workshop 1).

Thus, quality both absorbs and redistributes blame. It also re-stratifies participation, defining adequacy relative to institutional purposes:

> "You collect a lot of data, but you don't know how it was collected, who observed it. It's a bit challenging" (Workshop 3).

Citizens are thus moved along a ladder; from alerts to samples, novice to expert user with "registrations quality-assured by someone within the [expert] group" (Workshop 3). Validation

and levelling become tools of graded inclusion: empowerment is inseparable from discipline, and the capacity to contribute requires perpetual trainability. This same paradox extends temporally. CS promises responsiveness and immediacy through, for instance real‑time alerts, rapid feedback, but its outputs must undergo slow institutional digestion. A project lead recalls difficulties publishing citizen‑based results because the observations were "not very typical for plankton" (Workshop 1), though eventual publication in a policy journal re‑integrated them into the sanctioned rhythm of knowledge production. The citizen's momentary attentiveness is folded into the longue durée of expert verification and peer review. The dispositif depends on aligning incommensurate tempos: fast enthusiasm and slow credibility – without collapsing their difference.

9.4.3   The Moral Technologies of Citizen Science: Governing Participation between Democratisation and Austerity

Across the above-mentioned scenes, democratisation and austerity no longer appear as separate forces but as mutually conditioning rationalities. Under austerity, citizen participation substitutes for dwindling institutional capacity; under democratisation, it legitimises new forms of control. The more CS is positioned as inclusive, the more it requires calibration, credentialing, and hierarchical assurance. As one microbiologist put it:

> "The aim of democratising science is usually behind… if we are focusing on data quality… we still need expert evaluation and quality checks; volunteers may contribute 'only' to sample collection" (Workshop 1).

What appears as complementarity thus conceals an asymmetry in epistemic authority. Participation is invited through care and curiosity but governed through risk management and liability. In Finnish materials, the same designer who introduces "score points" and "fixed monitoring locations" also stresses safety thresholds: "We never explicitly say that it is safe… we always warn," aligning citizen classifications with Coast Guard practice (Workshop 3). Here, motivation becomes an instrument of governance – a moral and affective technology for managing hazards and maintaining data flow under austerity. The dispositif of CS thus fuses empowerment and constraint: participation as obligation, observation as discipline, and enthusiasm as infrastructure.

To mark the conflict more sharply: the discourse that CS "widens observation" depends on keeping citizens close as perceivers; the discourse that CS is "cost-effective" depends on rendering those perceivers auditable—licensable drone pilots, levelled app users, contributors whose images are calibrated and whose records can be flagged as "non-validated". The first discourse requires subjectivities of curiosity and care; the second requires subjectivities of compliance and comparability. When both are invoked at once, the "citizen" is pulled between being a person whose knowledge matters and being a component in a pipeline whose outputs must be made to matter. The field resolves this not by choosing, but by multiplying interfaces, like feedback emails and scoreboards; open maps and back-offices; easy picture uploads and hard validation gates, so that different values can be partially connected without being made fully commensurate.

This diagnosis thus prepares the analytic move of the next chapter. The tensions documented here are not failures of implementation; they are effects of partial connections between trajectories that

cannot be fully merged. Democratisation connects to austerity through quality/validation, but only partially. In Strathern's sense, the dispositif thrives on such partial connections: the same image can be a moment of civic care and a unit in a calibrated dataset; the same person can be an engaged participant and a trained operator; the same platform can be a public-facing map and a gatekept back-office. The cost of holding these partial connections together is continual work on subjects, motivating and training, and continual work on data, welcoming and excluding, retaining and marking. The bloom of CS in the 2010s, then, is not an overcoming of contradictions but a regime for living with them: widening who sees, while tightening how seeing counts.

9.5   Sub-conclusion of Part 1

We traced how SSH produced the 'citizen' as critical interlocutor capable of contesting knowledge frameworks, while natural sciences constructed the 'observer' as disciplined sensor whose credibility derived from standardised protocols. The 2008 financial crisis and subsequent austerity governance provided the conditions of possibility for these incommensurable subject positions to converge strategically, producing what we identify in the following part as a hybrid formation: the 'citizen scientist'. In this light, the citizen scientist in MCS arises neither purely citizen nor fully scientist but something more complex: a hybrid subject position that exists because of, not despite, attempts to maintain categorical purity. Yet acknowledging hybridity raises critical questions, namely how do these hybrids formations actually function? If citizen scientists are neither-nor, how do they connect to scientific institutions expecting pure categories? How do hybrid data achieve credibility in systems designed for standardised inputs? Part 1 showed that these tensions exist through genealogical emergence, but what Part 2 now examines is the relational mechanisms through which hybridity becomes manageable, if never fully resolved.

10   Part 2: Present
(Im)possible Totality of Partially Connected Scales

"The more hybrids are suppressed – the more categorical divisions are made – the more they secretly breed. Their present visibility is just that: the outcome of present awareness of this process"

Marilyn Strathern, *Cutting the Network* (1996, p. 522).

The following part employs Marilyn Strathern's relational anthropology to analyse how hybrids create partial connections based on the argument that current MCS practice operates through largely unexamined scale-making processes that perpetuate paradoxes rather than resolve them. The shift from genealogical to relational analysis reveals hybridity not as problem to be solved but as the generative condition of contemporary CS—yet one whose potential remains constrained by unexamined scale-making practices. Drawing on the notion of partial connections to analyse how MCS depends on hybridity while also managing it through scale-making, we analyse how citizens are connected to science enough to contribute observations, but not enough to determine validation, interpretation, or recognition. Tracing how observations become portable data shows that scaling is not neutral translation: it is a series of cuts that retain what fits scientific infrastructures and discard what does not. Through analysis of expert discourse and interview, we outline through merographic network cutting and scale-making how Science, Citizen, Citizen Scientist and CS as their own wholes are […] a circuit of connections that joins parts that cannot be compared insofar as they are not isomorphic with one another" (Strathern, 2004, p. 54). Only by making these implicit scale-making practices explicit can we possibly establish a reparative design foundation to reimagine how different scales might connect more equitably.

10.1   Identifying Wholes and Partial Connections

In Part 1, we argued that the developments in STS and social science during the late 1990s, together with the aftermath of the 2008 financial crisis, established the conditions of possibility—those historical circumstances that render particular formations thinkable and practicable (Foucault, 1970). These conditions enabled incompatible subjects to strategically converge within the framework of governmental austerity, ultimately driving the surge of CS in the 2010s. Against this backdrop, we can expand into the realm of Strathern in how such an accelerator also created a partial connection between the whole of the citizen and the whole of science. Before diving into analysing these two wholes, independently, we zoom out and depict several other wholes with partial connections to CS. Based on the genealogical analysis in which we demonstrated how different kinds of actors—whether academic, policy and/or governmental (see some of them mentioned in Figure 1)—played roles in shaping how CS within a marine context became both legitimate and governable. These were not just scientists or policymakers, but coalitions of theorists, ministries, EU programmes, and professional associations who made CS operable as both critique and governmental practice.
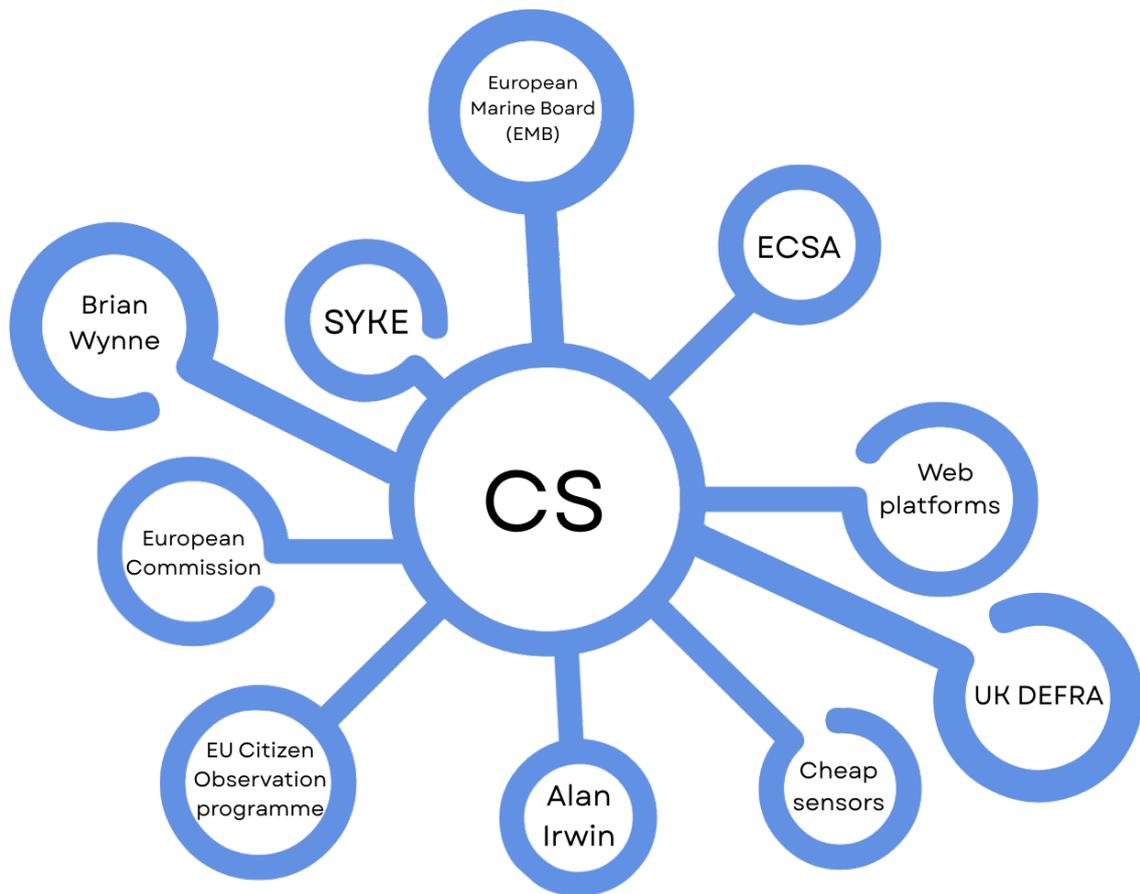
Figure 1: Network of (Non-)Actors of CS

The assemblage of different (non-)actors illustrated are all depicted as separate wholes with each of them having contributed to CS in their own way. Their understandings and individual utilisations of CS that, in turn, contributed to resistances, developments and/or extensions to CS as both a concept and practice, made CS a whole (Strathern, 1996). The ideas, critiques, feedback, re-evaluations constitute the partial connections that link to CS, and it is also these practices which constantly push the categories between scientist and non-scientist; data collector and knowledge producer; inclusion and exclusion. The multiplicity of perspectives and the ongoing debates among diverse actors highlight the challenges in defining CS, also seen when Expert B was asked how they would define CS:

> "It's a very good question and something I actually think about quite a lot because I might know (…) But if we look at how ECSA also defines CS, I do think it would be helpful maybe to think that science or research is involved some one way or another and that's where I start maybe to think when we talk about co-creation of knowledge, let's say for urban renewal, we might be doing things together with stakeholders and we might be co-creating measures and also knowledge, whether that is CS is for me debatable and I'm not sure it's beneficial to call that CS" (Appendix V).

The quote underlines the expert's struggle in stabilising a definition: "It's a very good question and something I actually think about quite a lot (…)", reflects what CS literature so often points out; how there is not yet a stabile definition of CS because it is under continuous debate. An attempt

at categorical clarity occurs by highlighting the ECSA's definition, i.e. purification, but it is followed by an example of a proliferation of hybridity when the informant mentions "co-creation of knowledge" in the example of urban renewal where whether it is "beneficial to call it CS" indicates how there may be other ways of defining the practice.

The long-standing challenge in defining CS, including separating it from terms or practices like crowdsourcing, participatory research or the likes of others, represent attempts to narrow down on its scope, multiplying roles and relations which exceed simple dichotomies between professional and non-professional, or between data collection and analysis. Yet the quote exemplifies how definitions can expand, contradict, and overlap, producing – or representative – of hybrids rather than purity, particularly when different stakeholders come together in e.g. urban renewal. This underpins what Strathern – through Latour – puts forward: that actual reality produces hybrids, i.e. entities and phenomena that are mixtures or combinations of what purification tries to separate. The more scholars, institutions, and practitioners that try to define and stabilise what CS is by drawing boundaries, e.g., citizen vs. professional; data collection vs. analysis, the more ambiguous and hybrid the category becomes. CS therefore appears less as a bounded object and more as a moving arrangement of practices, infrastructures, and roles. Purification efforts do not remove hybrids, in fact, they relocate them into the margins where participation and authority are negotiated whole by whole, case by case, actor by actor.

10.2   Science as a Whole

Expert B's highlights how "(…) it would be helpful maybe to think that science or research is involved some one way" (Appendix V) which implies that science is not only closely linked with CS, but a central part. In this light, science its own a whole understood through the partial, recursive, and sometimes contradictory overlaps between its practices, infrastructures, and discourses (Foucault, 1997; Strathern 1996; 2004). And within science lies the scientific trajectories outlined in Part 1 in which convergence between SSH's participatory ideals and the natural sciences' traditions of disciplined observation illustrates how science is held together by partially connecting, yet simultaneously incommensurable, values, logics and standards (see Figure 2). For example, through technologies that promote standardisation processes and discourses promoting democratisation of knowledge that constitute partial connections (Strathern, 2004) particularly representative of each scientific tradition.
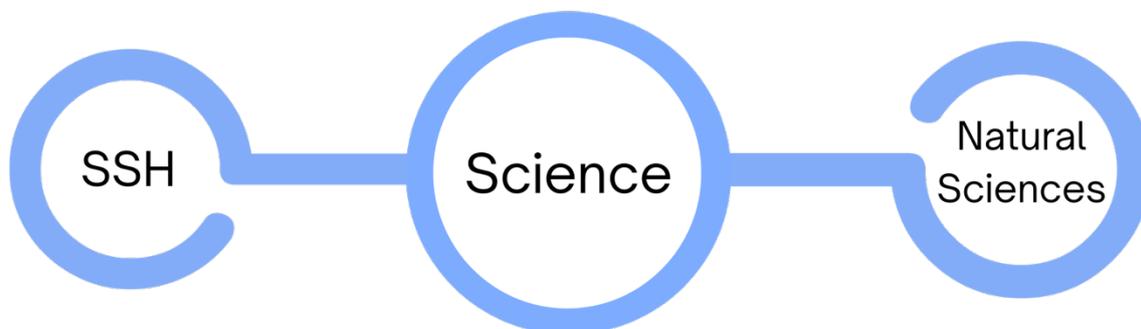
Figure 2: Science, SSH and Natural Sciences as Separate Wholes

Rather than synthesising SSH and the natural sciences into one unified "science," we treat them as partially connected wholes with different norms of evidence, legitimacy, and public engagement (Strathern, 2004). The relevance for CS is that being scientific is not one thing but a negotiation resulting in CS appearing as its own whole (see Figure 3), partially connected to the wholes of science, SSH and natural sciences. In establishing this, we resist notions that CS *lies* within science and simultaneously the idea that science is a totality.
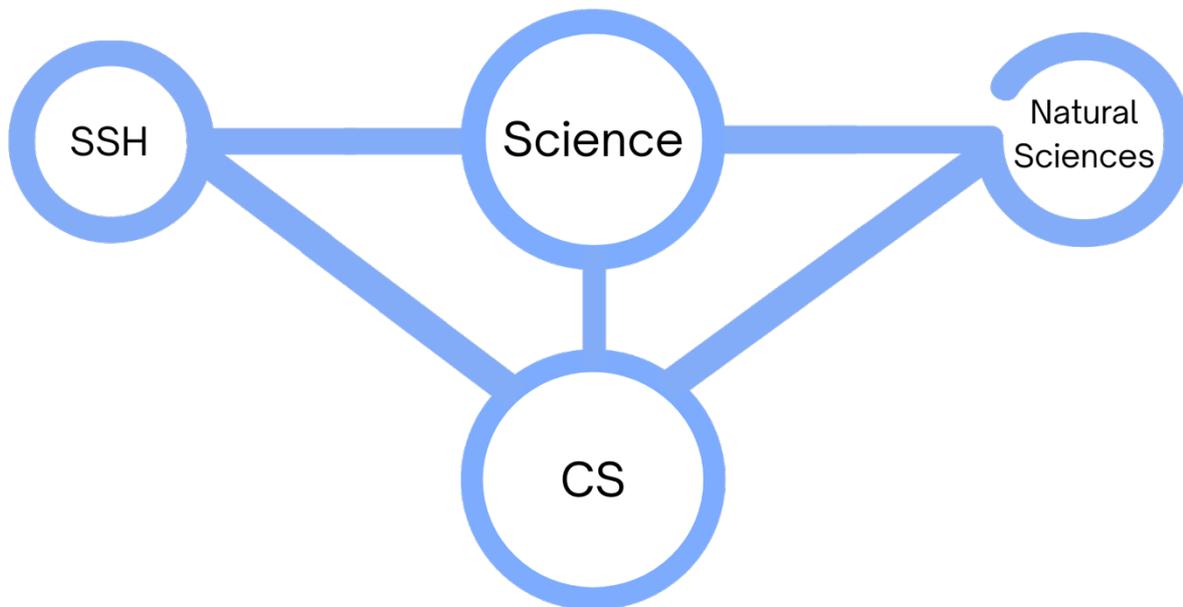
Figure 3: CS, Science, SSH and Natural Sciences as Wholes

10.2.1 Resisting the Notion of Science as a Totality – Amplifying the Notion of Science and CS – and All the Rest – as Wholes

A totality perspective in which the idea is CS as situated within science is represented in Expert B's remark about how "[research] it can entail CS activities, but not all part of the co-creation process necessarily sits in science" (Appendix V). Similarly, the idea that CS data can supplement – not substitute (professional) scientific research – is viewed in how CS is expected "not to exist on its own" but rather to "complement existing processes and data" (Expert B, Appendix V). This perspective frames CS not as generating knowledge in its own right, but as additional to science; valuable precisely because it supplements perceived gaps, yet insufficient to stand independently. Such a stance is not isolated to one interview but appeared repeatedly (see Appendices VIII, IX, X), reflecting a shared assumption that CS must orient itself toward the epistemic, methodological, and institutional standards of science in order to be legitimate.

In distancing ourselves from the perception of science as an already-given totality into which CS is inherently integrated, we move to analyse science, citizen, and citizen scientist, and ultimately CS, as separate wholes. Through Strathern (1996; 2004), CS cannot automatically be included as a component of science, but instead occupies its own domain, differently constituted and governed. Drawing on the conception of scales and cutting of the network, we demonstrate how, in effect,

citizen data undergoes a process of absorption: it is reshaped to 'fit' scientific measures and subjected to standardisation. The data undergoes processes of becoming scientific in which standardisation, arguably, becomes the scientists—the professionals'—audit tool through which they can set standards aligned with science. Through this process, CS is positioned as both useful and subordinate, always in relation to the imagined totality of science rather than as a knowledge domain in its own right.

Still, each whole (e.g. CS and science) have parts that overlap and contribute to science as a whole – and vice versa. These categories shape, and ultimately determine, the specific wholes of identities being claimed, which may themselves be construed merographically as parts of a broader set of identities (e.g. SSH and natural sciences). Thus, having unsettled the presumption that CS is merely an annex to science, we now turn to the second figure that is usually stitched into this hierarchy: the citizen. If science cannot be treated as a pre-given totality that swallows CS, then neither can the citizen be taken as a ready-made slot into which participants are inserted. The next section therefore asks what happens when citizen, too, is approached as a whole that brings its own histories, asymmetries and powers as opposed to the taken-at-face-value, generic public invoked in many CS projects.

10.3   Citizen as a Whole

Equivalently to how science is a whole, so is citizen. Citizen as a whole differs in conceptual form from citizen as a subject outlined in Part 1, contributing with knowledge to science as a whole through partial connections. Extending on this, we retrospectively refer to Haklay et al.'s (2021, p. 5) definition of the citizen as "members of the public". By this definition, a professional scientist would, arguably, also be considered member of the public – or public in power. By that definition, citizen in CS projects is not the publics, but a specific type of public that can be subjected to the knowledge production (Foucault, 1982). Within a CS context, the term, citizen, is being borrowed, to describe citizen scientist. Here, defining the citizen to distinguish from professional scientists, aiming at purification of terms and roles, creates a hybrid: *the citizen scientist*. However, still categorised as the citizen, it becomes those in power, the professionals that choose a meaning to connect the term.

An example is in the following excerpt where scientists in CS project, Phenomer, describes how they, essentially, choose which citizens are eligible to participate based on a given set of criteria:

> "And you know, we will take part of them and have a stand and tell people about the project and there have been a few communication campaigns where we sort of canvassed the harbour masters of various ports around the coast of Britain. These are posters up in different places to target the, you know, recreational boating crowd (…) Of course, they have been trained as well as the, you know, receiving the sea water and stuff, perhaps even more important is the communication" (Experts from Phenomer, Appendix III).

The excerpt demonstrates how scientists preliminarily 'cut the network' in terms of what types of citizens they are looking for before conducting CS (Strathern, 1996). In effect, they create a citizen scientist as a whole. This is further exemplified albeit in a different way when an informant states:

> "From a governance or a policy or even a citizen's point of view, you can't have a citizen. I mean, if it becomes a full-time job to do something, then it's not CS anymore, right? There needs to be a limit to how much you can engage people in doing, I think just from respectful of their time and interests"

Treating citizens as wholes in CS does not imply uniformity or full-person inclusion in science—each already brings a complete life of relationships, skills, limits, and concerns. CS simplifies this complexity by focusing only on project-relevant traits (e.g., time, reliability, instruction-following), sidelining the rest. Wholes are scalable units created by such cuts; thus, CS reduces the full citizen to a narrower, routinized role integrable into scientific systems—shaping participants via governmentality into standardised contributors. Cuts are made in distinguishing the citizen scientist from a professional scientist, in which the cut becomes the limit imposed on volunteer, citizen scientists' engagement with a project. In the latter quote, time functions as a partial connection which links citizen scientists to professional researchers through intensity of engagement, but it simultaneously marks a boundary. Once participation traverses the threshold into full-time commitment, the definitional contours of citizen scientist blur into those of research professionals. As such, in making cuts, the network constructs both the possibilities and limits of hybridity and affiliation within CS. This definitional tension mirrors the broader dynamics of the citizen scientist as a constructed whole, balancing democratic invitations with scientific usability.

10.4   Citizen Scientist as a Whole: Created from a Tension

The citizen scientist emerges from a tension that projects invite participation and democratic imagery, but they also channel contributions into forms that science can validate and use. This tension becomes visible in what participants expect in return, especially whether their work is put into use rather than serving merely as a symbol of democratisation:

> "They've [students part of iNaturalist CS project] been out collecting this [data] themselves. It's their own sample that they're working on. It's not something that's just ready for them, that they are then offered in in the lab. It's something that they brought in themselves and that's what they are going to work on. So that also makes them care a bit more of it on of the work that they're doing. They underlined in those interviews that they like very much the idea that it can be put into use. It's not just because it could be an exercise for the sake of the exercise" (Expert C, Appendix VI).

In the illustrated case of the iNaturalist project, students are representative of citizen scientists and they have a partial connection to science as a whole through the ability to comply with the data standardisation conditions, primarily curated through a natural science ontology, within especially the context of marine science. It shows not only how science becomes a standalone category to which citizen scientists as non-professionals can be connected to in a way that is not solely about participating, following a SSH rationale, but the feeling of meaningfully contributing in a way that is not "just because it could be an exercise for the sake of the exercise". In this way, the example

also highlights the difference in simply participating for the purpose of democratisation and participating because one is contributing to science as a whole where the data collected is "put to use". This duality also underlines how different genealogies of science are partially connected to science as a whole (see Figure 2). However, what this examples also brings to light is Strathern's notion of *scale*. That students want their contributions to be put to use illustrates how science becomes an object of the students' willingness to apply the data they generated. The importance is laid on how the data is mobilised to be scaled (up) to science. The citizen scientists as wholes are gaining some ownership and agency through participation in relation to its use. They have a perceived control over what is scaled (up). As opposed to the example from iNaturalist, in Workshop 2 an expert highlighted gamification as a tool "to ensure data quality" through increased citizen scientist motivation, demonstrating how citizen scientists become objects of the gamification processes to achieve quality data. Using gamification demonstrates how the citizen scientist becomes subjectified to science, particularly the strain of science that appeals to the natural sciences.

Consequently what these examples reveal are how the citizen scientist arises through a tension of being valued as a knowledgeable participant whilst also being considered a cog in a data machine; continually pulled between subjectification, inhibiting the potential to be both. It is exactly this tension that makes the citizen scientist a separate whole – neither absorbed within the citizen as a whole, science as a whole nor CS as a whole. Significantly, Strathern's notion of cutting is inseparable from that of scale, as cutting constitutes the very act through which complexity is organised and relations are made visible. In the context of CS, such cuts delineate what can be scaled up as legitimate knowledge and who can be recognised as a contributor, thereby exposing the asymmetries that shape how the citizen scientist comes into being as both a participant and a governed subject. Together, these cases show that scaling is never neutral. Cuts decide what counts as a contribution, who validates it, and what forms of participation become visible as CS.

10.4.1 Changing the Scale Between the Citizen and Citizen Scientist

In practical terms, the citizen as a participant in a CS project may oscillate between being positioned as a citizen and as a citizen scientist, depending on context, task, or recognition. This movement creates partial connections where roles overlap, shift, or become visible through specific actions. This could, for instance, be when some data are included while other are not. This is exemplified by an informant that provides a scenario from the CS project, the Amber Barrier (see Appendix IX):

> "Because I might be part of the Amber Barrier movement, but I go out on my own: I map the barrier, I put it into the app and then, I kind of thought of something, but I can still be just me versus let's gather around your local river in your neighbourhood only and then let's do something here. Then maybe you also need the participants to interact more and it's become something else and about the strategies and the way we work needs to be different and for this time long term versus short term involvement" (Expert B, Appendix V).

This example highlights how participation in CS is not uniform but varies according to the temporal scope, social context, and collaborative dynamics of engagement and/or participation. Participants may act independently or collectively, with differing degrees of interaction shaping their roles and contributions. These variations underscore the partial and shifting nature of citizen roles, as their connections to both science and to each other fluctuate along axes of time, motivation, and participation. Such fluidity exemplifies how structural conditions, and interpersonal relations, among others, mediate the boundaries between being a citizen and a citizen scientist. These boundaries can appear simultaneously flexible and enforced through project protocols and standards. Still, both the citizen and the citizen scientist are subject to project protocols, data management standards, or audit cultures, analyse as infrastructural cuts that both link and differentiate the citizen scientist from the citizen.

For example, knowledge and experience about the specific CS project appear as a partial connection that differentiate a citizen scientist from a citizen because their deepened involvement makes them – and their contributions – more likely compliant with data standards, partially connected to the whole of science. Extending on this, we observe that the distance between a citizen and a citizen scientist; and a citizen scientists to a science is determined by the shared partial connections between each of them. This distance is further mediated by at which point the network is cut (Strathern, 1996). What is cut from the network happens in accordance with the scale of scientific methodology and data standardisation, which is a subjectification connection from citizen to citizen scientist: Therefore, in order for data to avoid being cut, one must subject themselves to the scale of cutting in order to make a successful connection to CS as a whole.

10.5 What and How Data are Scaled?

Having outlined how science, citizen, and citizen scientist exist as distinct wholes with partial connections, we now turn to the concrete practices through which data travels between them. Scale is not an inherent property but is assigned through situated practices that determine what counts as legitimate knowledge (Jensen, 2007). For instance, CS re-scales science by creating entry points for citizens without prior scientific training, while simultaneously re-scaling citizen observations to fit scientific infrastructures. The value and mobility of data—whether citizen observations count and where they can travel—depends on which scaling practices are applied and by whom. Understanding how these scaling processes unfold in practice reveals that they are never neutral acts of translation but are instead selective cuts that retain what aligns with existing scientific standards and discard what does not. The following cases trace this process through concrete examples of how citizen contributions are validated, standardised, and mobilised across different project contexts.

10.5.1 Negotiating Legitimacy within Science: Student Contributions, Scientific Authority, and the Process of Scaling

Drawing on the above example of how students were motivated by their collected data being put to use and not just for the sake of involving them highlight how the value of participation depends

on the kind of participation, which can be driven by different scientific discourses: Participation driven by democratisation speaks to a SSH ontology while participation contributing to the furthered use of data – and not just for the sake of it – appeals to a natural science ontology. While such a distinction risk appearing as a binary, both dimensions are still constitutive of what science as a whole entails. This interplay between seemingly divergent ontologies becomes particularly evident when one considers how the data was handled in practice. While the students primarily engaged with the analysis of their own collected data, some subsets of the same data were simultaneously extracted by professional scientists for incorporation into ongoing research:

> "We realised quite early on that this [expand the ability to do larger geographical sampling over a larger area] was not possible to do ourselves. We could not drive up to every single lake and stream, and then we came up with the idea: What if we fused the research we're doing with these detection systems that are capable of detecting eDNA with high school students? They could start out by collecting a water sample in their own lake or small river, and then in advance they could post a sample by ordinary mail. A lab technician could then extract all those samples that come in from all the high schools, and then later on the high school students themselves could come in and use the samples they provided" (Expert C, Appendix VI).

Technologies such as the detection systems represent the standardisation processes that happen within the iNaturalist project through which eDNA is identified. Such a system scales up collected data as well as cut data that are not eDNA. Not only that, but at the same time, the lab technician extracts samples that qualify for further research gathered by citizen scientists, and in doing so determines what constitutes a legitimate contribution that can be scaled for research use. This shows how standardisation, in the shape of technologies and validation status, mediates a process of scaling as well as cutting citizen-generated data such that it can be partially connected to science as a whole (Strathern, 2004). Not only this, but one quote in particular suggests that there is a process to which the citizen scientists themselves can scale in stating that "they could start out by" and "advance", indicating the participants themselves can – through the provision of data to the CS project – decrease their distance to science.

Recognising that, in this specific case, inclusionary boundaries were shaped by the project's design, for instance by targeting high school students as opposed to a wider public, underscores how aims of awareness-raising actively delineate who can partake and how participation is valued (Appendix VI). In this sense, the example not only demonstrates how data is scaled up to science but also renders visible the relational work of cutting and connection through which scale and distance are produced, thereby echoing Strathern's observation that distance is imagined to separate not only entities but also the scales that are brought to bear upon them.

10.5.1.1 Technologies as Tools to Standardise

Another example illustrates how technologies standardise data such that it becomes 'scaled up' to science, and by effect reducing the distance to science as whole. In the following example, it is the RBB platform that creates a partial connection between CS, the citizen scientist and science as individual wholes:

"The RBB platform is used for gathering the information (…) if they are experienced users or if they are newcomers to this area and as always with CS data, one must assess what is the reliability of the observations. If it's obviously wrong, we need to take it out of the dissemination, but if it's somewhat usable, we accept it, (…) so for example, in here we have a location on a lake with a lot of data being added and the system automatically generates certain graphs to be seen" (Workshop 3, Appendix X).

While this demonstrates how aspect of CS as scaled up, it simultaneously illustrates how some connections in the network are cut, for instance, those data that are not "obviously wrong". However, the question remains to what extent is data obviously wrong, and who are able to make those cuts from the network. Despite active participation from citizen scientists, many remain peripheral to the scientific whole, reinforcing Strathern's idea of partial connections because wholes are connected peripherally rather than fully merged. This part of the interview also clearly demonstrates how, depending on what kind of CS one conducts, a mutual understanding exists that citizens are not in a position to scale the data provided; but instead, this task is left to the scientists. This is where "the professionals" enact a role as those who can scale up or down the information citizens provide. Therefore, despite carrying democratising values that perhaps seek to flatten any power dynamics between citizens and scientists, CS cannot be understood as a flattened collective erasing hierarchical difference, but as a dynamic scale-making process. In this process, attributes, roles, and forms of knowledge are selectively connected, always shaped by context, negotiation, and partial translation, revealing both the promise and the limits of collaboration across different worlds.

10.5.2 A Case In Which CS is Proven to be its Own Whole

Having demonstrated how data travels through standardisations processes, through technologies, in order to decrease the distance to science as a whole, we also note cases in which the scale also aligns with aims of CS: to draw on local knowledge, thereby scaling science to incorporate citizen scientists' experiences and observations. The following excerpt exemplifies the negotiation process, including the development, translation, and local adaptation of a scientific app for public engagement. It illustrates how elements from each whole—science and citizen—are selectively bridged through language and practice:

"The Amber app, which was then some app that we could use ready from the shelf, (…) was in English, translated into Norwegian and that was important for both to ensure participation… consolidate around how do we talk about these things in Norwegian? What do we call the different aspects? For example, in Norway we call barrier and landing cinder, which is then a word that leans towards the fishing community, whereas in Sweden they're chosen another wording" (Expert B, Appendix V).

The translation of the app from English to Norwegian, and the accompanying debates over terminology, shows how some scientific attributes are adopted (e.g. translation of terms, technology infrastructure) while others are adapted or resisted (e.g. choices of local wording, contextual relevance). For example, the Norwegian choice of "barrier and landing cinder", leaning

towards fishing community language, demonstrates how citizen interpretations shape what scientific knowledge becomes locally resonant and relevant in order to eventually scale up data input gathered from citizens. The negotiation itself becomes a site where partial connections are enacted: collaborative translation, discussions over wording, and field tests with students – through the master's student – all illustrate Strathern's insight that shared platforms are never formed from entirely merged worlds, but instead, from selected fragments contributed and adapted by each community (Strathern, 2004). This process underscores how science cannot – and by definition, should not – fully detach itself from citizens' lived realities within a CS project.

Nevertheless, whereas earlier examples illustrated how data from citizens were scaled up toward science, this case reverses the direction of scaling by showing how science is itself scaled down and adapted to incorporate local knowledge and experience. Adaptations to the data standardisation tool were made, influencing what aspects of science become locally meaningful. The Amber app's design required relatability to the users' everyday contexts, prompting the standardisation tools to absorb local idioms while still supporting data's upward scalability once collected. Notably, the app performs a double function: it translates science into citizens' linguistic worlds while simultaneously filtering and scaling their contributions back to scientific frameworks by cutting irrelevant data from the network. This dynamic means that bridging does not result in total integration but in the construction of partial connections, which always recognises the persistence of difference, the necessity of selectivity, and the potential for ongoing negotiation.

As attributes such as terminology, technical features, and participation practices are negotiated for inclusion, the result is a hybrid space, which is neither entirely scientific nor entirely citizen-based, and where partial connections enable functional collaboration. The app's ongoing adaptation and openness to further change highlight how scale itself is made relationally in this process. The two wholes do not merge but continuously attempt to bridge each other, revealing that scale-making is a provisional and negotiated act that depends on which attributes can travel between worlds and which remain embedded in their respective communities.

10.6   Sub-conclusion: The Core of the CS Problem – A Matter of Scaling

The relational analysis reveals hybridity in MCS not as a flaw to purify, but as a generative force sustained through partial connections and unexamined scale-making practices. Drawing on Strathern's framework, MCS arises from distinct wholes: science, citizen, and citizen scientist and CS that relate without merging, where network cuts standardise situated, embodied observations into abstracted data for scientific networks, cutting crucial context and perpetuating misconnections between local/personal scales and universal/standardised ones. Platforms like RBB or iNaturalist negotiate these scales asymmetrically: citizen contributions scale upward via validation protocols and technologies that filter usable data, while expert practices scale downward through selective amplification, enabling collaboration yet maintaining hierarchies where citizens contribute labour without authorship or interpretive control. Interview and ethnographic evidence traces how experts implicitly manage these scalar paradoxes where citizens are trained but uncertified, acknowledged but unauthored, which reproduces governmental tensions from Part 1's austerity convergences without explicit resolution. Scale thus emerges not as neutral translation but relational work that privileges scientific metrics, foregrounding power in who cuts what is

deemed as legitimate knowledge. Reflexive re-design demands making these processes visible because reconfiguring partial connections could enhance citizen agency over scaling, using hybridity as a means to link mismatched scales between wholes that lay the groundwork for reparative (M)CS futures.

11   Part 3: The Future
Repairing the Partial Connections

"The desire of a reparative impulse, on the other hand, is additive and accretive. Its fear, a realistic one, is that the culture surrounding it is inadequate or inimical to its nurture; it wants to assemble and confer plenitude on an object that will then have resources to offer to an inchoate self"

Eve Kosofsky Sedgwick, *Touching Feeling: Affect, Pedagogy, Performativity* (Sedgwick, 2003, p. 149).

Having traced the genealogical origins of MCS's governmental paradox (Part 1) and mapped its contemporary operations through scale-making (Part 2), Part 3 adopts a reparative orientation to ask: what alternatives might be assembled from within existing infrastructures? Drawing on Sedgwick (2003a, 2003b, 2008), we identify moments where experts already resist the double discourse—making standardisation portable without abandoning traceability, redefining participation beyond data harvesting, and allowing multiple ontologies of good data to coexist. The reparative position does not resolve the tension between democratisation and scientific rigour by choosing sides; instead, it reconfigures their relation so both can continue. We examine how resistance functions as future-making (11.1), interrogate what counts as 'good enough' data (11.2), critique the participation ladder imaginary (11.3), and propose a trinary model: CS-C (Civic), CS-L (Learning), CS-R (Research), which spatialises competing purposes into distinct yet partially connected dimensions (11.4). This model refuses developmental narratives, treating civic agency, skill acquisition, and research contribution as equally valid endpoints. Only by making these plural purposes explicit can we establish a reparative foundation for more equitable MCS futures.

11.1   Resistance and Repair as Future Making

Despite Foucault not being a futurist, his account of discourse makes futures visible as the effects of governance and resistance. In this light, we treat Foucault's idea on resistance of discourse as a basis for future-making that keep collaboration liveable while renegotiating its terms. From the outset of bringing Foucault and Sedgwick together, we begin with the way that standards are defended and simultaneously opened up to scrutiny in current CS operation.

Expert C working in a natural science education and monitoring describes a workflow where student groups collect eDNA samples and submit them for analysis where he shares that "you get a lot of fun data, but you don't know which is which and what is what, and then we cannot use it," and such runs are "discarded" if they do not meet the agreed format (Appendix VI). Perhaps this is also the reason why he makes explicit that the material coming in from participants has to be in a strict format where each submission must follow a naming convention, contain the right metadata, include the appropriate positive and negative controls and match the expected run structure. On the surface this sounds like a classic expression of the scientific strand of the genealogy where authority protects itself by filtering lay contribution. Yet the framing lies within a broader account where he also insists on making the protocol lightweight, replicable across many classrooms and logistically possible for non-experts to carry out: The project "is not just an exercise", but something that "can be put into use" where "many classes" could repeat the work,

generating a sense of real contribution. This narrative represents a resistance to the double discourse in a specific way by, firstly, refusing the version of "participation" in which students are invited only to feel included and then dropped, and secondly, creating distance to the version of "standardisation" in which only accredited scientists are allowed to generate usable material.

This represents, instead, a middle zone is built in which the standard is made portable, and the barrier to enter (to participate and contribute) is lowered without abandoning the obligation to traceability. This exemplifies a reparative gesture, and the repair here is additive. The design does not solve the tension between democratisation and audit by choosing one side. It re-arranges the relation between them so that both can continue.

11.1.1 Redefining Participation as Cognitive Engagement

The level of participation of citizens proved a central topic for our interviewees, and especially one offered a definition of CS that challenges the narrow "data harvesting" model, posing it as an intervention in practice, not just as a theoretical correction. Expert A demonstrated the most articulate resistance to the double discourse comes, where, for her, CS demands "high level cognitive engagement" from participants, and not just labour at the point of data collection. This includes a role for citizens in defining the aims of the project and in decisions about method, and to achieve this training and shared framing at the beginning of the process is required, not only at the point of sampling. This, again, becomes a demonstration of resisting a strong current in the genealogy; that the idea concern CS is a cheap workforce bolted onto expert pipelines:

> "For me, CS is not just collecting data for scientists. Citizens should be involved also in defining the aims and in the methodology, not only in doing the sampling. That means they need to be trained, and they need to understand what they are doing, not just execute a task" (Expert A, Appendix IV).

Here, the proposal for an alternative ordering in which training and shared problem framing are recognised as constitutive of CS itself instead of exposing the tension in epistemological/power asymmetry. This reparative reading offers a picture of: if one wants to call a project CS, one must fund and organise for citizen participation at the level of definition and method, not only use them as cheap data collectors.

These different gestures of repair expose a deeper structural fault line: not all forms of expertise carry equal epistemic weight. The asymmetry is not only between citizens and scientists but also within expert communities, especially across disciplinary boundaries where interdisciplinary power asymmetries also threaten reparative futures. Expert A describes how natural scientists in consortia often treat SSH contributions as outreach rather than epistemic core (Appendix III), reflecting the genealogical dominance we traced in Part 1. More critically, she warns that current pushes toward large-scale data reuse risk erasing minorities and local realities: "When the only thing that counts is what can be aggregated at continental scale, the subtle parts of experience and situated environmental knowledge risk disappearing" (Appendix III). This tension between aggregated scalability and situated specificity becomes central to reimagining CS futures because a reparative response holds the potential to reconfigure the very terms of interdisciplinary collaboration.

11.2 Mystery of 'Good Data' in CS

There is no shortage of debate about what counts as quality data, and these debates are never purely technical. Data quality categories are negotiated within institutional power structures, inviting both resistance and repair. In Part 2 we argued that "citizen science", "science", "citizens", and "scientists" are not nested wholes, but partially connected configurations whose relations are made and remade through cuts and scales. The question becomes not simply whether citizen data meet an abstract scientific standard, but what gets treated as "good enough" to move across worlds, and who benefits from the cuts that make that movement possible.

Seen through this lens, data standardisation is not rigid imposition but strategic facilitation that allows certain citizen outputs to circulate across partially connected worlds, often with tensions and costs. This is the mystery of good data in CS: 'good enough' is not a fixed threshold but a reparative negotiation that tries to hold partial connections together without erasing what citizens are measuring and why. In Strathern's terms, standardisation is one way of cutting and scaling citizen practices so they can enter partial connection with institutional science and policy—sometimes as equals, sometimes at the cost of being made legible on institutional terms. In Sedgwick's reparative sense, the point is not to purify citizen data into standard science, but to build trustable interfaces that keep collaboration liveable while still allowing citizen accounts of harm and care to demand response.

This is also why good data matters for inclusivity. If we take partial connection seriously, inclusivity in CS is not only about recruiting more diverse participants; it is about defending and elaborating the relations that let citizen scales of observation be recognised as producing data that count. 'Good enough' names the practical moment where those relations are worked on: it authorises citizen-generated worlds to connect with institutional worlds without being forced to surrender their specificity. In this sense, "good enough" is both an epistemic claim and a political one—an attempt to make citizen evidence bearable and actionable within governance while preserving the situated purposes that brought it into being (Balázs et al., 2021, p. 147; Gabrys et al., 2016; Stankiewicz et al., 2023).

Recent work reinforces this plurality. Balázs et al. (2021, p. 147) show that "good enough" is often stakeholder-specific choice, showing how protocols for metadata, uncertainty documentation, and fit-for-purpose framing help prevent predictable misalignment failures. This is exactly because scientists require reproducibility, policymakers require provenance, and communities require usability. Importantly, this does not resolve quality into one stable definition. They (2021) emphasise the plurality of quality notions in CS, with many competing interpretations of what good means depending on the intended use of data. Nevertheless, missing metadata or uncertainty statements can invite distrust cascades, amplified by the assumption that CS belongs within science and should therefore meet scientific norms by default. At the same time, the disadvantages of standardisation persist. Stankiewicz et al. (2023) emphasise Luxembourg's Water Blitz, where citizen measurements may score lower on methodological precision while scoring higher on empirical coverage, enabling governance pressure without claiming rivalry with official science. Yet over-standardisation can depoliticise CS's situated missions by forcing local observations into institutional aggregates that erase specificity, warning that poorly documented citizen data can also trigger reactions, where institutions dismiss all volunteer data as untrustworthy (Balázs et al., 2021).

11.3 Repairing the Lineage-Ladder Future Imagination in CS

If we take seriously the conclusion that there is no bad CS data as such, only data that are good for different purposes and, in Strathern's terms, for different scales, then the next step is to examine how the mainstream discourse has come to normalise one particular idea of goodness in CS. In much of the state of the art, the quality of a CS project is equated with the depth of citizen involvement in what is defined as scientific work. The more citizens do, and the more closely their activity approximates professional research, the better the project is assumed to be. This is where the future of CS is very often imagined; along a lineage that runs from light-touch contribution toward ever more intensive participation.

11.3.1 The Participation Ladder as Lived Practice

Participation typologies have been central to establishing this lineage Bonney and colleagues (2009) distinction between contributory, collaborative and co-created projects, (Shirk et al., 2012)Shirk et al.'s (2012) framework linking participation depth to outcomes, and Haklay's (2013) four-step ladder from crowdsourcing to extreme CS have been widely reproduced in handbooks, reports and design guidelines. While later work adds dimensions like cognitive engagement and data sharing, the basic structure remains a scale of increasing involvement (Haklay et al., 2021). Expert D explicitly frames the development of CS through a power gradient:

> "In the monodisciplinary, it's only the biologists that have the power. So you can understand the scale in terms of power. You have biologists in power, then you have researchers in power, and then in the third category you have more equal power distribution of the citizens, scientists, the biologists and the social scientists and humanities researchers" (Interview with Expert D, Appendix VII).

Here the future appears as a participatory 'evolution': the more categories join scientific research, the more 'mature' it becomes. This is not merely an abstract academic ladder; it is a lived imagination that circulates in practice.

From a reparative perspective, we can acknowledge that these models did important work, helping name the difference between exploitative and participatory configurations and resisting a narrow vision of CS as unpaid data collection (Hecker, Garbe, et al., 2018). Expert D's retrospective captures this: "We wanted more like, OK, what's in it for the lay people... they are not just butlers of marine biologists. They should also benefit from it" (Appendix VII). Yet he also notes that as CS becomes 'hyped', these 'old forms' face increasing de-legitimisation, suggesting co-creative formats now function less as aspirational options and more as evaluative standards against which all projects are judged. The ladder thus shifts from descriptive tool to normative pressure.

This linear imagination permeates policy documents and reviews, where co-created projects are framed as the most innovative and desirable form, implicitly positioning contributory projects as less advanced despite acknowledging CS's diversity (Hecker, Garbe, et al., 2018; Science Europe, 2018; Vohland et al., 2021). That compulsion matters because it turns a plural field into a single storyline of progress, one that can haunt projects whose obligations require different cuts and scales.

11.3.2 Two Problems with the Ladder Imaginary

There are at least two problems with taking this lineage as the primary way to imagine the future. First, it folds multiple dimensions of value into a single axis. As Shirk et al. (2012) themselves note, outcomes for science, participants, and social-ecological systems do not align automatically (2012). A highly co-created project may excel at empowerment but struggle to produce regulatory-compatible data, while contributory monitoring may generate robust datasets with modest agency. When the ladder is read as a temporal sequence rather than as a set of different configurations, it becomes difficult to see these as equally legitimate futures answering different obligations.

Second, the lineage model tends to treat citizens as junior scientists in the making. Expert A's definition makes this explicit by linking CS to 'typical scientific tasks' and 'high level cognitive engagement' as requirements: "citizens should be intended as a way... to grant to them some kind of high-level cognitive engagement in scientific research... such non experts… are doing typical scientific tasks." On the ladder imaginary, the highest level is where citizens take over most researcher functions. This can be empowering in some contexts, especially where communities build research capacity in response to environmental injustice (Jaeger et al., 2023). Yet our interview material and critical literature suggest this is not the only way to imagine inclusive futures. Chilvers & Kearnes (2015) argue that participation should be understood as diverse, emergent and relational, and that attempts to stabilise fixed models of 'good' participation can close down alternative paths. Gunnell et al. (2021) similarly shows that co-created CS, while often celebrated, can reproduce hierarchies if treated as the unquestioned apex rather than one form among many.

From our reparative reading, the problem is not that Haklay's (2013) ladder or related typologies are wrong. It is that they can easily be read as a developmental narrative where projects should move along the sequence over time. Projects that deliberately maintain contributory structures— whether for regulatory compliance or participant preference—risk being misread as lacking ambition, even when fulfilling their specific obligations effectively. In the rest of Part 3, we therefore shift focus from lineage development to a reparative guide for our model. Instead of proposing ascent toward extreme CS as the desired future, we specify how different configurations of participation can be made more inclusive and less damaging by defending partial connections, clarifying obligations, and stabilising the kinds of 'good enough' that allow citizen-scaled data to count without erasing their situated character. Our trinary model emerged from reading our informants for moments where they already enact such plurality—refusing to collapse civic agency, learning, and research into a single hierarchy. What follows spatialises these refusals into a reparative infrastructure.

11.4 Modelling a Trinary System

Our trinary system of CS starts from the recognition that reparative work takes different forms in different contexts. Instead of a single ladder of progress, we specify three legitimate purposes that can stand on their own while simultaneously connect when useful (meaning, they are partially connected). People may participate in one, two, or all three at the same time. Each purpose defines its own notion of goodness, and all three are treated as equally valid endpoints rather than stages (See Figure 4).

CS-C (Citizen Science for Civic)

Oriented to citizens' collective local ontology and epistemology and to civic agency, problem definition is local and outputs are directly useful to communities and public decision making.

CS-L (Citizen Science for Learning and Skills)

Oriented to mutual learning, training, and scaffolding, citizens and scientists co-design activities that develop research literacy and practical competence. Here, training, mentoring, and progression are first-class obligations.

CS-R (Citizen Science for Research)

Oriented to research-grade collaboration, participants contribute with extended knowledge and skills to tasks that require calibration, provenance, and audit trails, for example, divers helping collect benthic data in restricted areas.

Figure 4: Trinary System of CS

These three purposes are partially connected and mutually supportive. They diversify the reason for doing CS and allow for the treating of data quality as fit for purpose rather than as a single pass or fail standard. A record can remain in CS-C for civic action or move, with documented translation, into CS-R for research reuse. A participant can learn in CS-L and then choose to stay there or take on CS-R responsibilities without penalty for choosing either path.

This design is meant to prevent a new hierarchy from forming. Goodness is plural and purpose specific. For CS-C we value measures such as time to feedback, community uptake, and citizen co-sign on decisions. For CS-L, progression through micro-credentials, learning gains, retention, and learner-initiated proposals are valued. Lastly, for CS-R we value inter-rater agreements, calibration stability, documented provenance, and reuse in research and policy. These scorecards are displayed side by side and are never collapsed into a single index.

These three dimensions are rooted in literature, ethnographic data and a reparative reading of our informants. With the previous analysis of 'good enough' data demonstrating that data quality is a negotiated cut rather than a universal standard, it logically follows that the purpose of that data must also be open to negotiation. This brings us to the first node of our reparative model.

11.4.1 CS-C

CS-C (Citizen Science for Civic) refuses the containment narrative where citizens are merely sensors for a scientific totality; instead, it posits that citizens possess the intellectual authority to define the scientific problems relevant to their own lives. Grounded in our ethnographic data, CS-C is designed to validate local ontology, by which the specific reality lived by communities and the civic agency is prioritised over academic publication. This dimension is anticipated with Irwin's foundational definition of CS, which envisioned a science that assists the needs and concerns of citizens rather than simply using citizens as data collectors for professional scientists (Irwin, 1995). The first mission of CS-C is to legitimise local ways of knowing. Traditional scientific methods often rely on standardised, coarse-grained data that can obscure local realities (Scott, 1998). Expert

B highlighted this epistemic gap, noting that standardised maps often fail to capture the granularity of local environments:

> "...that's maybe exactly also where local knowledge can play a role because either because people are out on the ground and seeing things that you don't see. Or they have local knowledge that is not reflected in other maps..." (Appendix V).

In CS-C, data quality is therefore defined by its loyalty to this local reality. The goal is a rapid epistemological justice that is trying to ensure that community members are not merely subjects of study but are recognised as knowers (Fricker, 2007). This aligns with Jaeger et al.'s (2023) call for perspectival realism in CS epistemology (see Section 8.2), where knowledge is not universal but situated within specific communities and scales. Expert A, reflecting on a project involving people with dementia, argued that the CS approach was necessary not just to extract data, but to allow participants to shape the research reality itself:

> "Mainly because the CS approach was intended to be appropriate because we needed a lot of knowledge from these people. And we also wanted to empower them in order to impose, let's say, in this way, their own perspectives in the production on in the design of this app" (Appendix IV).

Unlike CS-R, where questions are derived from gaps in academic agenda, CS-C requires that problem definition be anchored in immediate community needs. This bottom-up approach is more similar to with (Haklay, 2013, p. 116) concept of "extreme citizen science", where communities control the scientific process from the outset. Expert D helped to illustrate this shift from abstract research to urgent, localised problem-solving:

> "Rather than going out and say...now we have a very important problem near the coastline. There are so many algaes we need to understand why this pollution is in this area? Okay, how can we solve that problem? Ah, we can do it by CS because there are so many stakeholders here that really want to understand and improve the situation along this coastline" (Appendix VII).

Here, the quality of the project is understood and measured by its relevance to the coastline stakeholders, not necessarily by the global generalisability of the algae data. The cut is made by the community. The whole being investigated is not the global ocean, but this specific coastline with this specific problem that is defined or sensed by the local. In the CS-C model, the 'goodness' of the project is measured by its responsiveness to this local definition, validating the local ontology as the primary context. This intellectual capacity of citizens goes beyond mere problem identification; it extends to the design of the inquiry itself. If we recall to Expert A's quote, the use of the word "impose" is significant because it suggests a reversal of power where the citizen's perspective is not a variable to be controlled, but the governing logic of the project. This aligns with our reading of (Strathern, 2004), where the citizens are not contained by the scientists' methodology; they are a partially connected whole that exerts force upon the methodology.

Finally, the ultimate mission of CS-C is civic agency. While CS-L focuses on learning and CS-R on data production, CS-C treats political and social influence as a valid scientific output. Turrini et al., (2018) argue that CS acts as a bridge between science and policy, but our model suggests that for

CS-C, the policy impact is the primary deliverable. Expert B articulated this distinction clearly, separating the act of data collection from the power to influence:

> "You have the data part, but you have also the other part that's a little bit about agency and opportunity to influence. Maybe questions or actions or things that are also relevant for the science we do" (Appendix V).

In the CS-C, a project is successful if it increases this opportunity to influence, effectively redistributing power through the ownership of evidence. In this light, the reparative work of CS-C is to sustain an infrastructure where data becomes a tool for influence. It validates that the citizens' motivation is a legitimate scientific endpoint, not always needing to be cut from scientific networks. By establishing CS-C, we acknowledge that good quality data is data that is sufficient to grant citizens the agency to intervene in their own partial worlds.

11.4.2 CS-L

If CS-C is defined by the cut that prioritises civic agency, CS-L (Citizen Science for Learning and Skills) is the dimension that provides the capacity for that agency. While traditional hierarchies often treat education as a secondary or a means to ensure data quality for researchers (CS-R), our trinary model positions CS-L as a distinct, sovereign whole. Its goodness is defined by the transfer of power through the transfer method. Here, the goal is not merely to train better assistants for scientists, but to cultivate critical literacies that allow citizens to mobilise data for their own ends (CS-C) or contribute to formal knowledge (CS-R) as they choose. This dimension is structurally necessary because, as our informants reveal, without a robust learning infrastructure, the other two nodes fail. CS-R collapses due to poor data quality, and CS-C collapses due to a lack of technical confidence.

The most profound need for CS-L is to dismantle the barrier between expert and layperson. Expert C challenges the gatekeeping of science by asserting that scientific capability is not an identity but a practice. He extends this logic to CS:

> "You don't have to have a degree in academia. There is no requirement... They will question you. Have you done your study meticulously? Have you checked for false positives and negatives? (…) Everyone on the entire planet is free to submit and do whatever they want" (Appendix VI).

In CS-L, the mandate is to make this meticulousness accessible. By teaching the method, CS-L empowers citizens to find their own effective methods. This approach reflects Jaeger et al.'s (2023) process philosophy (see Section 8.2), which redirects attention from knowledge as final output to the cognitive mechanisms and practices of its generation. It transforms science from a closed club into an open toolset that citizens can appropriate for their own inquiries, validating non-standard but effective approaches to truth-finding. Yet crucially, CS-L acts as the bridge to CS-C. To mobilise effectively, communities need to understand not just what the data says, but why it counts (or why authorities might dismiss it). This requires a specific kind of data literacy, namely knowing what constitutes good enough data for a political fight.

Finally, CS-L is ethically required to prevent the exploitation of volunteer labour. Particularly considering Expert D's critique of the extractive model where citizens are treated as "butlers of the researchers" (Appendix VII). He warns against projects where natural scientists hold all the power and citizens merely follow suit. In this understanding, a good CS-L project is situated in reciprocity: what do the citizens get out of it? He advocates for projects where the goal is "to improve scientific literacy" so that participants leave with more than they gave. On the other hand, Expert B highlights an epistemic need for CS-L: one cannot govern or protect what one does not see. While CS-R seeks to fill data gaps, CS-L seeks to fill an awareness gaps. Discussing environmental governance, Expert B emphasises that the act of mapping or observing is a tool for creating a shared sense of reality. In her view, the need for CS-L arises because standardised, top-down maps often miss local realities. The previously mentioned quote about the local knowledge that cannot simply be pointed on the maps stresses that the learning here is bidirectional. It is not just scientists teaching citizens; it is citizens teaching scientists and policymakers about the local terrain. These reciprocity thoughts are what sustains the eco-system of CS. If the learning dimension is absent, participation becomes a transaction of labour rather than a partnership of curiosity. Whether a participant wants to publish a paper (CS-R) or stop a local polluter (CS-C), CS-L provides the necessary scaffolding, the methods, confidence, and the literacy, to do so effectively.

11.4.3 CS-R

While CS-C prioritises local relevance and CS-L prioritises skill acquisition, CS-R (Citizen Science for Research) is defined by the cut that prioritises the scalability, comparability, and institutional utility of data. In this domain, good data is not measured by how much the participant learns or how politically active they become, but by whether the aggregated data is robust enough to withstand peer review and contribute to generalisable scientific knowledge. Our informants reveal that CS-R is not just about more data; it is about achieving a specific kind of data that is impossible to generate through traditional means. To address this, the primary mission of CS-R is to achieve a scale of data collection that is physically and financially impossible for professional scientists to achieve alone. Expert C provides the definitive argument for this dimension:

> "We quickly understood we could not sample this many samples... we could not perform these many runs... It would be too demanding to go out and get all those samples" (Appendix VI).

In CS-R, the individual citizen's contribution is often a tiny drop in the ocean, which might seem insignificant on its own. However, the goodness of CS-R emerges from the aggregation of these drops. As Expert C notes, the motivation for the researcher is to obtain huge data sets that allow them to interpret something that a smaller, expert-collected dataset could never reveal. Thus, CS-R validates the citizen not as a local activist, but as a vital node in a distributed sensor network.

If CS-C allows for vernacular protocols (e.g., smell logs), CS-R demands strict adherence to standardised data procedure. Line argues that data to be useful for long-term environmental monitoring (e.g., complying with EU directives), it requires consistency and comparability over time. Without this standardisation, the data cannot communicate with existing scientific models.

Steen reinforces this by describing the strict set up required in his DNA projects. He explains that for the data to be trustable, participants must follow a rigid protocol involving positive and negative controls. If a participant deviate (for example, by switching a tube) the data is just thrown aside. In the CS-R dimension, this rigidity is not a flaw but a feature; it is the mechanism that allows amateur data to be treated with the same confidence as professional data.

The mandate of CS-R is to feed into established institutional frameworks. Expert D acknowledges that while we must be critical of power dynamics, there is a valid role for citizens in supporting professional researchers who "make a living out of doing research". In this mode, the successful endpoint is the integration of citizen data into formal databases (like *iNaturalist* or national monitoring bodies) that serve the broader scientific community. The reparative aspect of CS-R is that it opens the ivory tower, allowing citizens to contribute to the permanent record of scientific history. It recalls Steen's quote: "everyone on the entire planet is free to submit and do whatever they want", even if this is most hardcore scientific activities. CS-R ensures that this contribution is not just symbolic, but empirically valid.

11.5 Sub-conclusion to Part 3

Consequently, these three dimensions should not be viewed as fragmented steps toward a single scientific ideal, but rather as independent 'wholes' that function on their own terms, refusing to let CS appear simply as a minor or preliminary version of 'real' science. The citizens' data are not offered up to be absorbed, purified, and then reported upward into an already existing scientific whole. A project can exist entirely within the logic of one dimension without needing to satisfy the criteria of the others to be considered valid. For instance, a civic project (CS-C) that achieves political impact does not need to apologise for lacking the global scalability required by research (CS-R), just as a learning-focused initiative (CS-L) is legitimate even if it produces no data for external use. In this view, 'goodness' is not a vertical ascent up a ladder of participation, but a horizontal choice of purpose; a project is 'good' if it fulfils the specific ontological and epistemic goals of the dimension it occupies. Still, this independence does not imply isolation because these wholes are partially connected, creating a dynamic system where actors are free to travel forward and backward between dimensions as their needs evolve. A participant creates their own trajectory: they might enter through the door of learning, gain confidence, and shift into high-grade research, or conversely, start in research and pivot to civic activism when they realise the data reveals a local injustice. By replacing the rigid hierarchy of the ladder with this fluid trinary system, we recognise that data quality is not a fixed attribute but a negotiated relation. Whether one chooses to join one, two, or all three dimensions, the sign of good CS is simply found in the alignment between the actor's intent and the specific utility of the data within that chosen sphere. This world can and does partially connect to regulatory science but is not contained by it, which in Sedgwick's terms, is a reparative move.

Thus, the Trinary System is not merely a descriptive model; it is the infrastructure of the repair itself. By spatialising the mismatched wholes into distinct governable nodes, we resolve the haunting of the genealogy that has long plagued CS. The historical tension between democratic inclusion and scientific control is no longer a contradiction that must be forced into a single

hierarchy. Instead, the Trinary System gives these competing lineages a place to live where they do not have to contradict one another. In this structure, the friction between the activist's need for agency (CS-C), the learner's need for growth (CS-L), and the scientist's need for calibration (CS-R) ceases to be a failure of the project; rather, it becomes the engine of a fluid, interconnected eco-system. By validating these distinct ontologies side-by-side, we dismantle the deficit model that views citizens as incomplete scientists. The Trinary System therefore offers a concrete way to stabilise the partial connections of the field, ensuring that the future of CS is not defined by how high participants can climb a ladder, but by how freely they can travel between the valid, vital worlds they help to construct.

12   Discussion

The following discussion addresses three persistent analytical tensions that cut across our findings. First, we suspend the 'citizen' as a fixed identity, treating it instead as an enacted subject position that shifts across different modes of engagement (Section 12.1). Second, we argue that the governmental paradox and mismatched wholes stem from treating one ontology of standardisation—legitimacy through portability—as the default route to credibility (Section 12.2). Finally, we examine how CS opens new avenues for scientific practice by demonstrating that rigour can be achieved through non-standard protocols, challenging the assumption that methodological conformity guarantees quality (Section 12.3). Together, these discussions ground our central claim: that repairing CS requires not better implementation of existing standards but plural ontologies of standardisation that allow different forms of knowledge to count on their own terms.

12.1   Suspending the Citizen

We have deliberately avoided fixing the 'citizen' as a stable identity. Our genealogical diagnosis (Part 1) and analysis of mismatched wholes (Part 2) revealed that defining the citizen through negation—as non-expert, amateur, layperson—collapses under empirical scrutiny. As demonstrated in Part 2 (Section 10.3), experts in Phenomer and other projects preliminarily 'cut the network' by targeting specific citizen types—recreational boaters, harbour masters—before participation even begins. Yet this binary definition fails to account for expert amateurs (e.g., retired engineers contributing technical data) or activist scientists (e.g., marine biologists using community data for local advocacy). As Latour (1993) argues, attempts to purify 'Science' (nature) and 'Society' (citizens) inevitably produce hybrids that fit neither category neatly. When projects police these boundaries, insisting citizens act like junior scientists to be valid, they reproduce the very hierarchy they claim to dismantle.

Therefore, rather than stabilising this unstable category, we suspend it to interrogate the logic that constructs it. We treat 'citizen' and 'scientist' not as fixed sociological identities but as situated subject positions enacted within CS dispositifs—positions that are partially connected, periodically re-cut, and made more or less liveable through reparative practices.

12.1.1 From Identity to Enactment

This suspension draws on Strathern's (1992) concept of the dividual: a partible, relational person whose capacities and responsibilities are composed through shifting relations rather than expressed by a single fixed identity. Analytically, this shifts our focus from who participants are (identity) to what positions they enact (performativity) in practice and what obligations, rights, and forms of epistemic authority they are assigned, contest, or take up in particular settings. Thus, read through Sedgwick's reparative stance, this orientation attends to additive arrangements that keep heterogeneous forms of participation workable without forcing them into a purified citizen/scientist binary (Sedgwick, 2003). Our Trinary System operationalises this logic, configuring CS-C as, not a space for non-experts, but for enacting civic ontology. A university

professor concerned about local pollution enacts the citizen role here, engaging with local meaning-making. Equivalently, but differently, CS-R is not reserved for professionals but for enacting standardised calibration. A non-credentialed amateur enacts the scientific role by adhering to strict data provenance protocols. Then, CS-L is a space for enacting becoming, where focus is on skill progression rather than data output. This pushes the question to become: Which mode of engagement is currently being enacted? This theoretical manoeuvre justifies treating CS-C, CS-L, and CS-R as parallel, equally valid endpoints. They are distinct modes of existence that require different valuation of metrics, rather than rungs on a single ladder of progress.

12.1.2 Addressing Power Asymmetries Without Fixed Identities

We must, however, address a critical anthropological tension in this suspension: Does removing the definition of the citizen risk flattening power dynamics between a marginalised resident and a highly educated volunteer? We argue that while the category of the citizen is fluid, access to specific modes of engagement remains uneven. As Strathern reminds us, partial connections are not symmetrical. A participant with high science capital may slide effortlessly between CS-R's technical demands and CS-C's civic goals, while marginalised participants may find CS-R's technical and linguistic barriers prohibitive. This inequality is precisely why our Trinary System is a necessary reparative intervention. Rather than relying on a single evaluative standard, we validate CS-C and CS-L as terminal, high value end-points in their own right, refusing the judgment that reads them as incomplete approximations of real science, meaning CS-R. What is at stake here is not only epistemic order but affective endurance—who can stay, who is exhausted, who is rendered not quite legitimate, and whose contributions become bearable within infrastructures of credibility.

We disrupt the hierarchy privileging technical access by shifting evaluation from persons to arrangements. We do not demand marginalised subjects transform into scientists to have value. Instead, we demand the system build conditions where diverse enactments of citizenship count without being forced onto a single extractive scale. We assemble multiple modes of participation that sustain practice under risk, partiality, and unequal access, keeping differences visible rather than erased.

12.2 Ontolog(ies) of Standardisation

Standardisation is often presented as a practical way to secure 'good data'. In the case of the RBB platform, for instance, enabled coordination across monitoring sites and automatic graph generation. In STS, standards are analysed by tracing infrastructures, classifications, and power dynamics—who sets rules, who is included or excluded (Bowker & Star's work, 1999a, 1999b). We build on this work but shift focus from how standardisation is done to what standardisation is assumed to be. Our findings suggest that the governmental paradox (Part 1) and mismatched wholes (Part 2) stem from one dominant understanding: legitimacy tied exclusively to portability and comparability.

12.2.1 How Single-Ontology Standardisation Produces Paradox

The governmental paradox becomes clearer from this angle. If 'good data' means comparable and portable data, authority rests with those who set and enforce standards. Governance then becomes tied to expert control over what is considered as proper evidence. In our cases, participation is welcomed but citizens contribute labour, coverage, and observations while their own ways of knowing are treated as uncertain unless translated into standard formats. In practice, participation becomes conditional on standardisation—inclusion through compliance that reshapes citizens into standard data producers.

As Part 2 demonstrated, standards require cutting relational, context-dependent observations into comparable units where a process that often frames local complexity as 'noise' rather than questioning whether categories match the situation (Section 10.6). This friction appeared repeatedly: the Amber Barrier app required Norwegian fishing terminology to maintain local relevance (Section 10.5.2), while RBB's automated validation systems struggled to determine what counted as "obviously wrong" data (Section 10.5.1.1). People do extra work to adapt, translate, smooth, omit in order to make observations fit. When fit is poor, mismatch is framed as 'error' rather than reflecting that categories may not match the situation. Comparability can require crude simplification, leading to a totality: an airy thinness rather than worldly thickness.

12.2.2 Toward Plural Ontologies of Standardisation

Section 11.2 in Part 3 offers an empirical hinge to rethink all of this. Across our material, 'good data' does not behave like a stable property guaranteed by protocols alone, but depends on whether data is recognised as good by different groups. Data can be produced carefully yet doubted if it does not match familiar rigour expectations. Conversely, data can travel easily if it fits accepted forms, even when local production conditions are unstandardised. This suggests 'good data' is a relational achievement depending on trust, credibility, purpose, and shared ways of valuing evidence. A single standardisation model will misread practices as weak simply because they do not travel well, though they function well for their purpose. Many projects have great value precisely because of their thickness in being close to place, experience, and unique local concern.

We therefore propose thinking in terms of plural ontolog(ies) of standardisation in CS. We do not aim to dismantle standards but to challenge treating one kind as the default route to legitimacy. Different standardisation models can be legitimate in different situations, depending on what the project attempts, what is at stake, and what kind of evidence is needed. This is standards for standardisation: a meta-level way of choosing and justifying how a project should standardise, rather than assuming that more standardisation is always better.

This plural approach changes how we understand tensions between participation and science. We do not advocate adding participation into a fixed system or keeping local knowledge separate from science. Tension eases by allowing more than one way for data to be valid. Some projects may rightly prioritise comparability and large-scale monitoring (CS-R). Others may need protected spaces where local practices stay active without being forced into universal categories (CS-C). Some contexts may require reparative arrangements where participation and evidence terms are

negotiated because histories of harm and exclusion shape the situation, thus to ensure local practices stay active and are not forced into universal categories (CS-L). This is why our Trinary System (Part 3) operationalises plural ontologies rather than a single default. CS-C validates local thickness that does not travel well; CS-R maintains comparability for institutional integration; CS-L builds capacity to navigate between these different registers. Each dimension legitimises different forms of standardisation fit-for-purpose, rather than treating portability as the only route to credibility. The governmental paradox and mismatched wholes persist when one ontology is imposed universally; reparative design holds them together by allowing each to operate where it works best.

One might argue that the problems could be solved with better implementation, for example, more training, better tools, comprehensive protocols, and more inclusive governances. These moves can help, but our analysis suggests they remain inside a single framework where legitimacy equals portability. In that framework, inclusion means becoming legible to standards, and mismatch is treated as deficiency. Our cases show instead that mismatch can signal where repair is needed—where the standard's picture of the world does not fit the world of practice. Our contribution, then, shifts the question from 'how to improve standardisation' to 'which ontology of standardisation is being used, and what does it produce'? The governmental paradox and mismatched wholes concern both power/participation and what standards assume knowledge must look like to count. By grounding this argument, we open space for alternative standardisation models that hold participation and scientific credibility together without requiring one to be reduced for the other.

12.3   CS Opens New Avenues in Using Scientific Tools/Methods: Practices Hold the Potential to Shape Trust in Citizen Science

The production of 'good' data in CS reveals a striking reversal: it is not always citizens who lack scientific understanding, but scientists who lack understanding of how citizens do science. In the eDNA project with high-school students, for instance, difficulties stemmed not from data inadequacy but from reviewers' confusion about methods that achieved scientific rigor through different protocols – simply by using scientific tools in a different way:

> "But what they could the reviewers; it was not that they didn't dislike it, they just didn't understand it to begin with and that was more… the difficulty in explaining that we can use the same machine, we can use the same tools, but we can use them in a different way and still have confidence at a scientific level as we expect for doing scientific papers and all that stuff" (Expert C, Appendix VI).

This reversal—where scientific rigor is achieved through non-standard protocols—exemplifies what we traced in Part 1 (Section 9.2): credibility has historically been tied to conformity with established procedures, making methodological innovation legible only with difficulty.

This observation opens a broader discussion about how notions of quality data are constructed and maintained within different epistemological traditions because even data produced by professional scientists is not always complete, perfect, or readily available. Thus, the demand for quality applies equally to CS data and to data produced within the scientific community itself.

Instead of treating citizen contributions as inherently less trustworthy, it becomes necessary to question what quality means in practice: Does it refer to spatial coverage, specificity, or fitness for a particular research purpose? Such reflection invites a shift from ontological certainty toward epistemological flexibility. Still we argue, that "just good enough data" (Gabrys et al., 2016, p. 1) is not only about exposing harm or proving institutional neglect as part of a paranoid stance that is organised around catching the powerful out; it is about assembling an infrastructure that people can actually live with. The point is to sustain an ongoing position from which one can demand to be heard.

The shift from 'your data are invalid' toward 'this is enough to require your engagement' (Gabrys & Pritchard, 2016, p. 10) exemplifies the reparative orientation our Trinary System operationalises. Rather than imposing a single standard, our model validates plural routes to legitimacy: CS-L builds the capacity to understand why different standards exist and how to navigate them; CS-C validates political sufficiency over methodological perfection, sustaining a position from which citizens can demand response; and CS-R maintains the rigorous comparability needed for institutional integration. Together, these dimensions transform 'good enough' from a defensive compromise into a strategic choice about which ontology of standardization serves the purpose at hand.

13   Research Limitations and Proposals for Further Investigations

The empirical material for this study is drawn exclusively from the perspectives of professional scientists, rather than citizen scientists, and this constitutes a key limitation, but it foregrounds the epistemic and institutional pressures that shape what counts as "research-quality" data within the scientific field. By interviewing scientists involved in or overseeing CS initiatives, we gain access to internal reflections on how credibility, validity, and data standards are negotiated and upheld— criteria that are not only applied to citizen-generated data but also to professional scientific work. As one informant noted, even data produced within well-established research institutions can be incomplete, inconsistent, or constrained by limited resources. This observation underscores that data quality is not a fixed or objective attribute, but a socially and contextually negotiated standard, contingent on purpose, scale, and interpretive frameworks. From this perspective, citizen scientists are not positioned as epistemic outliers, but as participants expected to meet the same methodological demands as professionals. The difference lies not in the standards themselves, but in the support structures, such as training protocols, governance models, and validation mechanisms, that help ensure data reliability in collaborative projects. Thus, focusing on scientists reveals the structural logic of credibility in science, highlighting how norms of measurement and validation extend across both professional and non-professional domains. This focus is analytically significant because it exposes the institutional expectations that citizen scientists are often implicitly or explicitly required to align with.

This scope choice, however, risks reproducing the asymmetry it seeks to analyse. Privileging scientists' accounts can reinforce a top-down view of legitimacy where CS is evaluated primarily through professional validation. We therefore treat this limitation transparently and use the expert-only vantage point to illuminate the institutional frameworks and gatekeeping mechanisms that structure inclusion in scientific knowledge production. Following Latour, we note the risk of a 'purification trap' that maintains artificial boundaries between scientific and non-scientific actors rather than treating them as co-constituted within hybrid networks.

Ultimately, the scientist-centered approach clarifies the institutional scaffolding of credibility while limiting our ability to analyse how citizen scientists themselves enact, interpret, and contribute to CS. Future research should place both perspectives in dialogue to build a more symmetrical account of knowledge co-production.

14   Conclusion

This thesis has traced how MCS emerges not as a unified practice but as a site where incompatible epistemological traditions converge under governmental pressure. Part 1's genealogical analysis revealed how austerity assembled SSH's democratising ideals with natural science's standardisation imperatives into a paradoxical apparatus. Part 2's relational analysis showed how this paradox operates in practice through scale-making processes that connect citizens to science partially, enough to contribute observations, but not enough to determine validation, interpretation, or recognition. Part 3 proposed a reparative alternative: a Trinary System where civic agency (CS-C), learning (CS-L), and research (CS-R) function as equally valid endpoints rather than stages on a single ladder.

This work shows how standardisation in marine citizen science (MCS) is simultaneously a technical pathway to better data, and a governance practice that defines what participation can be. Taking OBAMA-NEXT as a site where protocols, validation rules, and citizen participation are negotiated, we read documents, expert workshops, and interviews as traces of how 'good data' and 'good participation' are aligned or set against each other.

Three findings matter. First, the inclusion/quality tension is historically assembled. Today's standards inherit governmental expectations about control, comparability, and accountability that set upon paradoxical and forced merge. Second, standardisation scales through cuts. interoperability and aggregation are achieved by narrowing what counts as data and by redistributing effort and authority, often away from citizens. Third, data quality is not a single ladder but a situated and contested good; treating it as purpose-dependent creates room for multiple forms of credibility and participation.

On this basis, the thesis contributes a reparative trinary orientation for MCS standard setting (CS-C/CS-L/CS-R) that keeps multiple goods in view and makes standardisation decisions explicit, discussable, revisable, and inclusive. The goal is not to reject standards, but to design them so they can travel across scales without flattening the practices and relations they rely on.

A central limitation is the expert-centred lens. We map conditions of possibility more than lived participation. Future work should trial the trinary orientation in concrete standard processes and follow how participants meet, resist, or reshape the infrastructures that result.

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