

# Non-experts' participation in processes of scientific knowledge creation: The case of Citizen Science

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## Abstract

Public participation in science and technology, is currently being encouraged in order to fulfil the calls for a more engaging, transparent, and ethical way of governing technoscientific innovation. Several institutional documents argue for the need to enrol non-scientists into research programs; funding schemes devoted to public engagement seem to be paving the way for new baselines for knowledge creation and innovation paths that include the contributions of citizens. Citizen Science stands out as an opportune movement to lead non-scientists to contribute to scientific research projects and technological innovation, and it has given rise to a broad debate intersecting many sociological aspects linked to participation and community empowerment. However, the participation of non-scientists in data collection, analysis, and interpretation is not totally new; yet it has not had the same value across time, nor has it always been considered desirable. Indeed, volunteers' engagement and amateurs' contributions have been regulated differently compared to the current rhetoric of participation. This paper gives an account of the evolution of participation of non-experts through the lens of Science and Technology Studies, investigating its desirability, how it is governed,

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and whether it matches the promises of Citizen Science practitioners.

#### KEYWORDS

Citizen Science, participatory approach, public engagement, science governance, STS

## 1 | INTRODUCTION

Public participation in science and technology, or technoscience, is currently being encouraged in order to fulfil the call for a more engaging, transparent, and ethical way of governing technoscientific innovation. The European Research Area has promoted several institutional documents arguing for the need to enrol non-scientists in research programs (European Commission, 2020; European Commission Directorate-General for Research and Innovation, 2023); funding schemes devoted to public engagement seem to be paving the way for new baselines for knowledge creation and innovation paths that include the contributions of citizens. This paper aims to review the sociological scholarship concerning the contributions of non-experts to scientific knowledge creation. More specifically, this thematic review builds upon three branches of literature: Science and Technology Studies (STS), Public Understanding of Science and Technology (PCST), and the Citizen Science debate. In triangulating these three prominent branches I consider most quoted and widely accepted contributions about the role of non-expert allows a well-rounded overview of the relationship between scientific institutions and non-experts. Taking the three together gives rise to a vantage point from which to map the changing value of non-experts within the broader context of the relationship between science and society. Indeed, both STS and PCST have dealt largely with the issue of non-experts as a key category to understand the social shaping of technoscience, while more recently Citizen Science (i.e. the voluntary participation of ordinary people in scientific research activities; Silvertown, 2009) is publicly recognised as a ground-breaking tool to address the proper public engagement of non-experts in innovation and knowledge creation processes (Kullenberg & Kasperowski, 2016; Strasser et al., 2019).

From a science governance perspective, it is easy to record efforts by research funding institutions and governmental agencies to integrate non-experts into technoscientific innovation processes. For this reason, social scientists should be able in the future to highlight continuities and changes in this complex relationship and offer support for further research agendas in the topic of participation, addressing Citizen Science as of the most advanced proposals for engagement.

For this purpose, the subsequent section extrapolates some key categories from the three branches of literature that will allow us to track the path of this relationship across the subsequent sections of the paper. The next section will take into consideration some key issues developed around the categories of experts and non-experts, public engagement and science democratisation. The following section will then review the processes of science institutionalisation, highlighting its connections with politics and decision-making as part of the post-war social contract of science (Jasanoff, 2003; Wynne, 2015). More specifically the section will discuss the delegation to scientific authority and the separation between a 'lay-people class' and an 'expert class' as an institutional basis that reflects such a social contract (Bush, 1945; Fischer, 2000) a key tension in science governance (Borrás, 2012). A subsequent section will review Citizen Science as a tool to address issues of the democratisation of science and its impact on science, citizen empowerment and policy (Von Gönner et al., 2023), specifically considering challenges explored by the PCST and STS literature (Strasser et al., 2019) in response to what are considered the failures of a regime of exclusion of non-experts. The review will then focus on the role assigned to Information Communication Technologies (ICTs) in the current context of datafication (van Dijck et al., 2018), as ICTs serve as a triggering factor for participation and Citizen Science (Haklay, 2015; Triezenberg, et al., 2012; Wynn, 2017). Drawing on these elements, the review will

conclude by highlighting potential research paths about participation from a sociological perspective, connecting forms of participation and the shaping of these practices through ICTs.

The current development of the governance of technoscience, which is moving towards a growing contribution of non-experts, calls for a synthesis that is able to provide researchers in the social sciences with key references in order consider issues connected to such a trajectory.

## 2 | OF TECHNOSCIENCE: APPROACHES, STRATEGIES, AND ASYMMETRIES IN THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY

STS emerged as a distinguished research field in the social sciences between the late 1970s and early 1980s (Sismondo, 2010), integrating the study of processes of establishing scientific knowledge with the study of technological artefacts. More specifically, STS scholarship identified how research activities are necessarily interwoven with the technological devices that make them possible and, at the same time, how all technological artefacts, whether used in everyday life or in research activities, are nothing but materialised scientific knowledge. This approach refuses conventional distinctions between knowledge and its artefacts, collapsing into a single concept the knowledges, methods, tools, practices, and people imbricated in processes of innovation (Latour, 1987). Besides its conceptual value, the label has the advantage of allowing scholars 'to follow natural knowledge and its embodiment in material artefacts without taking position on what is science and what is technology' (Shapin, 2008, p. 3).

Scholars in STS focused further on how technoscience is embedded in social life (Sismondo, 2010), both in everyday practices (Latour, 2005) and in shaping those practices (Suchman, 2007) and social worlds (Clarke & Star, 2008), but also in connection with political opportunities for forms of participatory democracies (Chilvers & Kearnes, 2020).

In these regards, the PCST debate echoes this latter prospect: the idea of engagement and participation emerged gradually as the attempt to overcome paternalistic approaches towards non-scientists (Bucchi & Trench, 2021). The necessity to go beyond the claims of a rigid separation between science and society provides the baseline for politically legitimate innovation processes and scientific knowledge construction (Stilgoe et al., 2014). Nonetheless, according to Susana Borrás (2012), there is a key tension in science governance, consisting precisely in the role assigned to citizens as non-experts and it still holds nowadays.

In analytically addressing this tension, we can consider participation in technoscience as a two-sided coin: on the one side are the people that actively seek to participate, as advocacy or grassroots organisations and spontaneous groups that may contribute or just simply ask to take part in innovation processes (Smith et al., 2014), aiming at contributing to redesign of therapeutic protocols (Rabeharisoa & Callon, 2004) or denouncing cases of environmental stress (Allen, 2018; Berti Suman & Van Geenhuizen, 2019; Corburn, 2005; Gabrys, 2022). On the other side of the coin, we can consider those initiatives that aim at gathering non-experts as stakeholders, by inviting them in the attempt to foster dialogue (Bucchi, 2008; Irwin, 2008); the PCST literature lists a wide array of strategies ranging from public events, including science festivals (Jensen & Buckley, 2014) and open talks at a science café (Stephan, 2018) to techniques for public consultation (Joss & Durant, 1995; Van Bouwel & Van Oudheusden, 2017). The main common point between the two sides of the coin is the role assigned to people, or the extent to which people can gain access to those processes.

### 2.1 | Citizen Science as two sided-coin of engagement

Building upon on these features, it is possible to consider participation in a longitudinal perspective, tracking how it has changed across time. Indeed, we can notice how non-experts went through different stages according to different models of democratic participation in the governance of technoscience. Historically, there are plenty of examples of mobilisation from below of concerned groups (e.g. for patients, see Epstein, 1996; for residents in poor

neighbourhoods, see Brown, 1993) in collecting data going back to the 1970s (Mahr & Dickel, 2019), but they often are described as examples of political struggles.

Currently, as already mentioned, we see a trend of increasing institutionalisation of non-experts together with the broader call for participation in technoscience and innovation. Research funding agencies and research policy agendas integrate non-experts engaged in Citizen Science experiences as valuable contributors to science-making processes (European Commission, 2019; U.S. House of Representatives, 2016). This would help to realise a proper participatory turn in democracy and science governance, as has been widely theorised in STS and science policy analysis (Jasanoff, 2003; Joss, 2002; Pellizzoni, 2003).

For these reasons, Citizen Science has become a very opportune label (Bonney et al., 2009; Cooper & Lewenstein, 2016; Irwin, 1995) intercepting precisely processes of non-experts' participation as highlighted by the STS and PCST literature. Citizen Science as a label it is often considered as a sort collaboration in research paths defined by scientists and it may incorporate the experience of grassroots activation by citizens (Cooper & Lewenstein, 2016).

Currently, the desirability of non-experts' participation is relevant to many scientific fields. The examples provided throughout the text will explore different areas of application of Citizen Science, such as environmental monitoring, biology, and astronomy. This array of examples gives some sense of the most common areas of application of Citizen Science (Bonney, 2021; Fritz et al., 2019), which is often highly encouraged in order to support research into current global challenges such as sustainability as well as longer-term research agendas such as space exploration (Sauer mann et al., 2020; van der Hel & Biermann, 2017); secondly, it will be possible to achieve a view across both invited (i.e., 'top-down') experiences and uninvited (i.e., 'bottom-up', spontaneous) activities of concerned groups in cases of controversy (Allen, 2018; Berti Suman & Van Geenhuizen, 2019; Corburn, 2005; Fischer, 2000; Gabrys, 2016, 2022; Irwin, 1995; Wynn, 2017). More specifically, such revamping of the contribution of non-experts can be seen in a number of funding schemes for scientific research and innovation frameworks, such as the European Research Area's consideration of the Responsible Research and Innovation (RRI) framework (Von Schomberg, 2013) and open science, which openly appeals to Citizen Science as a way to enable citizens 'to make significant contributions and be recognised as valid European science knowledge producers' (European Commission, 2019). Current research policy agendas call for a dedicated reflection in social sciences about the trajectory of the engagement of non-experts and the opportunities and barriers for groups and individuals that are invited to enter processes of knowledge creation (European Commission, 2020; European Commission Directorate-General for Research and Innovation, 2023). In general, as shown by other reviews, this feature of Citizen Science is valued as a positive approach for effectively addressing challenges of participation and overcoming the limits (Hecker et al., 2019).

## 2.2 | Limits of public engagement and promises of Citizen Science

The expectations connected to potential benefits of engagement needs to be carefully considered—namely, how participation is actually configured (Bulkeley & Mol, 2003). In knowledge creation processes, engaging non-experts as a necessary component of research and innovation programs has already been proven to be at least controversial (Felt & Fochler, 2010; Mirowski, 2018; Stilgoe et al., 2014). Scholars in STS as well as PCST have denounced the limits of participatory approaches, accusing them of being more a formal obligation than genuine engagement, which can recursively reinforce the social distance between scientists and non-experts, keeping certain social groups out of decision-making (Chilvers & Kearnes, 2020). The way how the participative approach is actually performed require investigation (Felt & Fochler, 2010; Mirowski, 2018; Stilgoe et al., 2014). Research demonstrated that is sometimes illusive to apply participatory techniques blindly: a key criticism is the institutional and formal, rather than substantial, involvement of citizens (Irwin et al., 2013).<sup>1</sup> As reported by other scholars (Dawson, 2019) often public engagement is performed as business as usual rather than properly problematized; in doing so it can reinforce, class, race, gender and inequality. A 'proceduralised' effort of public engagement, possibly, incorporated in research

funding applications (Stilgoe et al., 2014, p. 6) would more likely produce a 'talk about the talk' (Irwin, 2006, p. 317) rather than overcoming the limits of non-engagement. Hence, disregarding the expectations public engagement might produce a perverse effect to reproduce exclusion. This echoes what others already noticed: involving most educated, less conflictual groups in attempt to perform properly the tasks envisaged by a participatory technique may produce side effects of involving only those groups that are desirable, thus replicating what it can be labelled as a machinery of consensus (Felt & Fochler, 2010). This seems to share the trajectory of participatory design that gained momentum since late '70s; in that case, participation shifted from the promotion of fora for encounters between firms and workers - a clear political mission to re-equilibrate power asymmetries - to a more product-oriented perspective privileging mostly usability for end-users (Bannon et al., 2018). Participation into design became a two-way learning process in which the latter bring knowledge of their needs and contexts of use, while the designers contribute by proposing technically feasible alternatives (Id.). Similarly, as PCST and STS debates have recognised, approaching participation in a proceduralised way does not help to enlarge participation; furthermore, it may increase marginalisation of already marginalised groups. The participation mantra (MacNaghten et al., 2005) across the years has mainly allowed to include citizens who have a specific profile: highly educated, already interested in scientific issues. This state of affairs contributed in reproducing presumptions of who the publics should be and what their features might be (Chilvers & Kearnes, 2020). This means that participatory processes are in any case limited in their ability to intercept groups and individuals that are not already 'visible' or, in some cases, that have a perspective that diverges from the mainstream.

Citizen Science seems to bypass these limits by involving non-experts in practical activities, fragments of scientific research that may actively engage them. A key and common feature of Citizen Science consists in data collection and data set creation, covering blind spots about a certain issue or solving complex puzzles related to data classification or even engaging non-scientists in the definition of research questions (Bonney et al., 2009). Such a practical orientation seems to give a proper answer to the calls for an active democratisation of science. Strasser et al. (2019) summarised the potential contributions of Citizen Science for engagement and open science as three promises. The first is enlarged participation: Citizen Science would promote the engagement of non-experts, expanding the array of people involved in the creation of scientific knowledge (through data collection in the first instance). Secondly, it would foster participation in a broad sense, including the governance of environmental issues; indeed, as many reviews have confirmed across time, conservation and environmental monitoring rely on the Citizen Science approach for data collection (Bonney, 2021; Conrad and Hilchey, 2011; Fritz et al., 2019). As Strasser and colleagues report (2019), that Citizen Science would improve scientific literacy among participants through their engagement in doing research has been proven valid for some projects in conservation and environmental monitoring (Bonney et al., 2016). Last, but not the least, Citizen Science activities are potentially unique in building 'new science' both in terms of geographical reach and in terms of perspectives on research and its application. These three promises would enrich technoscience and positively reverberate on the whole society.

### 3 | TECHNOSCIENCE, POLITICAL LEGITIMATION AND GOVERNANCE

Technoscience is a central feature of our daily life. Besides consumption through digital devices, technoscience is also part of the democratic governance, supporting, advising, and legitimising policy-making and configuring itself as a sound source of political authority, sometimes in this regard described as technocratic (Böhme & Stehr, 1986).

Key scholars in social theory have pointed out the role of technoscience in contemporary society in terms of the knowledge and expertise to manage contemporary risk (Beck, 1992; Giddens, 1990). A more dedicated and critical reflection about this comes again from STS scholarship; indeed, we are living in a technoscientific culture that affects our contemporary society (Bijker et al., 2009), although there are several indications that technoscientific authority has lost its relevance compared to past years (Lynch, 2020). However, scientific institutions still hold their cultural prominence within our society for instance in the public sphere, several daily publications on newspapers are about technoscience (Bauer et al., 2018). This is true despite the fact that already during the last decades of

the 20th century, scientific authorities may have suffered an increasing lack of trust (Jasanoff, 1995) and were not rarely contested in view of environmental and technological risks (Chilvers & Kearnes, 2015). Indeed, technoscientific institutions are struggling but still retain their authority as source of legitimation as the Covid-19 pandemic has showed (Crabu et al., 2021). In the case of environmental monitoring and observation, the scientific institutions and the apparatuses for the construction, use, and dissemination of data about the environment still contribute in shaping, and continuously re-affirming, the authority of political institutions (Waterton & Wynne, 2004). Technoscientific authority indeed may function as an external source of legitimation for political decision-making and as a necessary force for guaranteeing well-being. The configuration of science ruled for the public good as an uninterested and politically independent body with its own values echoes the original analytical proposal of scientific communities by Merton (1973). Currently such an ontological separation is considered outdated. About 40 years of STS have eroded the idea of technoscience and research as an ontologically distinct area immune to social variables (competition, cultural values, beliefs); nonetheless, the institutional distinction of who is -and conversely who is not-entitled to create, manipulate, and make sense of data for decision-making still remains. As a key feature of the relationship between science and society, the role of non-experts is not a new topic within STS. As the historian of science Steven Shapin recognised already 30 years ago: 'sociologists of science, on the occasions when they do consider the categories of science and the public, tend to focus upon the relations between two known entities' (Shapin, 1990, p. 990). Indeed, well-known discussions of this relationship in the STS literature concern specific issues such as health and medical epistemic authorities (Epstein, 1996), or the support for local disputes (Irwin, 1995; Wynne, 1987) especially in cases of environmental injustice, while some others proposed to work precisely on such a divide as a proper research agenda (Collins & Evans, 2002). All these contributions assume as a starting point the tension outlined by Borrás (2012) – a tension that relies on the separation between experts and non-experts and the issue of the authority of science.

### 3.1 | Separating experts from non-experts in practice

The STS outlook has contributed to scrutinising the processes that keep this tension active. Literature in this field can be divided into historical considerations of the construction of professionalisation of technoscience, and discussions of how the institutional distance is remarked in practice. As Elam and Bertilsson argued (2003), the separation between scientists and non-scientists can be tracked back to the Enlightenment; the Enlightenment model (Healey, 1998) became a key feature of modern societies, distinguishing between scientists and non-scientists by way of their formal training in technoscientific subjects and their role in a scientific institution (Fiske et al., 2019). Regarding the former, the history of science has noted that the distinction and hierarchical relationship between non-experts and experts hardened from the nineteenth century onwards (Shapin, 1990; Vetter, 2011). The authority of technoscience has been built across the years in many different ways, including the systematic exclusion of non-experts. Indeed, before the turn of the 20th century there were several examples of non-experts' contribution to scientific knowledge creation for specific services, such as for instance weather observation in the late nineteenth century in the U.S. (Vetter, 2011), or herbaria and bird counts (Miller-Rushing et al., 2012). This is highlighted also in several foundational publications of the Citizen Science debate; they claim the crucial role of non-experts in advancing environmental monitoring, which appears to be a rhetorical resource for supporting citizen science as an approach that gives back importance to the origins of scientific research on the field (ibid.). Nonetheless, the history of science has also shown that even in that supposedly golden age, the asymmetries were already present. Almost recursively, scientists excluded non-experts in a process of the institutionalisation of technoscience. Although some cases may be relevant showing the opportunities of a proficient collaboration the same interest, as in the case of curators of an early 20th century natural history museums and amateurs (Star & Griesemer, 1989), still it was the case of different social world (shaped by meanings, practices, values) which needed to be aligned. Considering examples of environmental monitoring and the observation of nature, the differing interests and goals between experts

and non-experts are more complex to be aligned; indeed, we can list at least three strategies used to inhibit the role of non-experts and conversely to reinforce the role of a class of specialists to be accounted as experts. A first strategy consists of not acknowledging contributions coming from amateurs, as described by Cain (2012) when official curators of natural history museums in the U.S. did not acknowledge the contribution by amateurs in mounting the exhibits, selecting specimens, and preparing dioramas. A second strategy consists in discrediting the category of the amateur by alleging a lack of seriousness and reliability, a process that is further reflected in the shift of meaning in the word 'amateur' from the older meaning of 'connoisseur' to a less pleasant 'dilettante' or 'incompetent' (Drouin & Bensaude-Vincent, 1996, p. 418). A third strategy is the inhibition of data collection by non-authorized sources, thus imposing a monopoly of a network of data points. This last strategy is well exemplified by the aborted attempt at participatory seismology in the U.S.S.R. in the early 1950s. For the sake of a centralised control of seismologic information, central Soviet authorities banned contributions from amateurs as well as the publication of any non-official bulleting referring to earthquakes, classified as a state secret (Aronova, 2017).

The three examples reveal processes of boundary creation (Gieryn, 1983, 1999) distinguishing between what is scientific and what is not and thus contributing in the demarcation about expertise. This distinction thus defines what is reliable and trustworthy; the same effect is contingently produced according to practices that define and reiterate a specific expertise demarcation, for instance questioning the robustness of any claim not supported by official data.

Distinguishing between who is entitled to interpret the signs of nature (Latour, 2004; Shapin, 2012) and who is not has several democratic implications. Such a process of institutionalisation of technoscience steering innovation and research (Brown, 1993; Macnaghten et al., 2005) assumes and reproduces this separation of roles. Such a separation reinforces the delegation of decision-making not only to elected representatives, but also to whoever owns the data to interpret a specific situation (Borrás, 2012; Fischer, 2000). Data ownership and interpretation legitimise highly informed decision-making but exclude those who have no access or control over how the data are produced. One celebrated model portraying innovation in society is known as the triple helix, comprising academic research, political decision-making, and firms the so-called Mode 2 (Etzkowitz & Leydesdorff, 2000); some critical commentators have painted it as an exclusionary model of non-experts, an 'iron triangle' locking citizens out of decision-making processes about science, technology, and innovation (McCormick, 2012). As Latour put it analysing the case of environmental policies, scientists/experts would be able to use a form of authority that is hard to contest by insisting on their ability to interpret the signs of nature (2004). This easily paves the way for cases of environmental injustices that hardly could be demonstrated if not supported by official data. This is the typical condition of grassroots' mobilisation of non-experts: claims in need of supporting evidence (Allen, 2018; Corburn, 2005; Minkler & Wallerstein, 2008) or experience that is not validated by official data (Wynne, 1996). When data are not available or accessible,<sup>2</sup> grassroots mobilisation has shown how non-experts can organise themselves around the practice of creating evidence as described by Gabrys (2019, 2016).

Therefore, alongside the issue of the right to participate in research and innovation as a strategic issue for contemporary society, the literature has revealed a structural exclusion from data.

#### 4 | CITIZEN SCIENCE OR SOLICITED AND UNSOLICITED CONTRIBUTIONS OF NON-EXPERTS TO SCIENTIFIC RESEARCH

Participation through the production of scientific data is a response 'from below' to the tension between roles in science governance. Therefore, grassroots participation in technoscience through data can be interpreted as a way to meet the call for a democratisation of knowledge (McCormick, 2012).

On the other side of the tension, research and innovation governance increasingly aims at integrating non-experts' contribution. As already mentioned, participation and engagement into science and technology is a step on the way to decentralising and creating 'more politically palatable' innovation paths (Mirowski, 2018, p. 177) towards so-called 'open science' (European Commission, 2019). This configures a participatory turn in democracy and

science governance (Jasanoff, 2003; Joss, 2002; Pellizzoni, 2003) moving beyond the so called Mode 2 (Etzkowitz & Leydesdorff, 2000); according to the RRI framework (Arnaldi & Bianchi, 2016; Von Schomberg, 2013) a proper and genuine engagement of non-experts may contribute to correcting the failures science and innovation relating to the social good as well as equity and inclusion (ibid.). The triple helix model has been updated into a four-helix model that explicitly includes society at large as fourth component of innovation (Carayannis & Campbell, 2009). This push for engagement, according to other authors, is meant to promote political legitimacy for decision-making (Wynne, 2006) and mutual responsibility between societal actors and innovators from an ethical point of view as a key feature to achieve in contemporary society (Von Schomberg, 2013).

Such a push towards engagement in order to realise a more engaging, transparent, and ethical way of governing technoscientific innovation (Ribeiro et al., 2017) relies on the contributions of STS and PCST to EU research and the innovation policy agenda. The report 'Taking European knowledge society seriously' (Felt et al., 2007) pointed out the limits and the failures of a model of science governance based on the exclusion of non-experts remarketing asymmetry between them and an experts' class. The STS and PCST debate deconstructed the images and representation of non-experts made by technoscientific authorities: often non-experts appear in policy documents as a hurdle for innovation because of alleged scepticism, mistrust, and generalised ignorance (ibid.). Besides highlighting these criticisms, re-elaborating the conclusion of the Lisbon Agenda (European Council, 2000) about including non-experts,<sup>3</sup> the report recommended integration of societal stances within the cycle of innovation, not only as a public to be enlightened but as citizenry to be included into critical topics that may affect their lives.

Currently the debate at the policy level has evolved significantly in the direction of considering non-experts as an added value. Practitioners' opinion converges on the idea of Citizen Science as a promising way to perform engagement, have a positive impact on scientific knowledge creation processes and influence positively policymaking (van Gönner et al., 2023). The analysis of policy discourse about Citizen Science seems confirm that the approach is seen in a positive light (Hecker et al., 2019) with clear endorsement by policy documents both in the EU (European Commission, 2018, 2020) and the U.S. (U.S. House of Representatives, 2016). As shown by the still ongoing Mutual Learning Exercise on Citizen Science, the European Commission actively supports common reflections in order to highlight good practices for Citizen Science initiatives (see for instance the last report of the European Commission Directorate-General for Research and Innovation, 2023).

Practitioners of Citizen Science have taken stock of STS and PCST contributions to non-experts' participation, promoting Citizen Science as a model to truly engage people in scientific research by addressing main issues related to the tensions in the relationship between science and society. Although there is not a single univocal definition (Haklay et al., 2021), there is agreement in considering Citizen Science as an approach that integrates non-experts into scientific research in a range of possible activities, from offering support for data collection up to developing research questions and co-designing research tools (Haklay, 2012).

The promises summarised by Strasser et al. (2019) describe the ideal contribution of Citizen Science as a unique driver in building potentially 'new science' both in terms of geographical reach and in terms of perspectives on research and its application. On the one hand, especially in case of crowdsourcing projects,<sup>4</sup> the data can cover so much territory in such a detailed way that would be impossible without a diffuse network of data gatherers; on the other hand, non-experts may contribute in defining research questions and providing interpretations, thus integrating upstream outlooks into the point of view of science.

What emerges from the discourse of Citizen Science is thus that obtaining the contribution of non-experts is a win-win opportunity. The elements described so far concur in addressing the goal for a larger participation, as required by the dialogical approach in the relationship between science and society and the need for public engagement (Bucchi & Trench, 2017). Moreover, they appear in line with the seminal idea of 'scientific citizenship' as promoted by Irwin (1995). These promises resonate further with experiences of data produced from grassroots initiatives. Besides the proposal by Irwin (2015, 1995), who first referred to Citizen Science<sup>5</sup> as a self-organisation of non-experts around data in environmental struggles, other similar experience have been labelled 'street science' (Corburn, 2005), 'popular epidemiology' (Allen, 2003; Brown, 2007), 'strong participatory science' (Allen, 2018), and

'citizen sensing' (Gabrys, 2016). Although the focus of the analysis may shift between the mutual learning during collaboration between experts and non-experts (Allen, 2018), the scientific practices of non-experts outside labs (Corburn, 2005), and the fabric of the social relationship during the process of creating data that were not available before (Gabrys, 2016), all the processes described focus on the mobilisation of non-experts in response to a condition of environmental stress.

The promises of Citizen Science as reconstructed by Strasser et al. (2019) do not exclude such a condition, but they broaden the opportunities for a collaboration to include non-controversial and less conflictual settings. A useful concept for making sense of these alternatives is provided by Mahr and Dickel (2019): they distinguished between invited and uninvited participation of non-experts to scientific research. This distinction makes it possible to further explore the triggers for participation of non-experts: on the one hand we have a top-down approach in which collaboration between experts and non-experts is designed by professional scientists; on the other hand, uninvited participation refers to self-organised modes of participation originating from the needs of civil society. Mahr and Dickel openly criticise the perspective of Citizen Science as a 'buzzword' or, in other words, as a method to be used instrumentally in research by scientists, reinforcing rather than subverting 'original power structures' (p. 41). This would deepen further the cleavage between experts and non-experts through a renewed institutionalisation: I already mentioned the institutional pull and the policy endorsement of Citizen Science flanked by the blossoming of national networks and supranational associations (CSA in the US, ECSA in Europe, CS in Australia) also trying to steer Citizen Science by providing guidelines. Among the many resources, the ECSA Ten Points are a clear example of a normative definition of Citizen Science (Haklay et al., 2021) in the attempt to define borders for what constitutes a proper Citizen Science activity.

STS researchers are aware that the mainstream narrative of Citizen Science is ambiguous (Cooper & Lewenstein, 2016; Strasser et al., 2019), referring to both uninvited and invited experience but practicing more often the latter.

What counts here is that there is clear evidence of a growing non-expert participation, in crowdsourced environmental monitoring projects as well as in other research domains. Several sources agree on the enabling role of digital technologies supporting such a blossoming that would expand non-experts' participation (Haklay, 2015; Triezenberg, et al., 2012; Wynn, 2017).

## 5 | ENACTING TECHNOLOGIES: ICTS AS THE PREMISE FOR ENLARGING PARTICIPATION?

Digitisation constitutes a critical change in most realms of our everyday life (Balbi et al., 2016), as several practices appear now reshaped by digital technologies, while others are not even conceivable without the mediation of ICTs. Processes enabled by ICTs are reshaping industrial production, cultural consumption (Beer & Burrows, 2013; Kitchin, 2014), as well as new opportunities for non-experts' participation. Citizen Science communities, both top-down and grassroots, have taken advantage of them already since the late 2000s. In the literature there is quite a consistent number of contributions describing how digital technologies can actively support participation of non-experts in scientific knowledge creation. Triezenberg et al. (2012) in this regard announced:

We are seeing tremendous potential for research in this relatively unknown arena with significant promise for improving the learning, scientific, and behavioral outcomes of citizen science programs.

(p. 225)

Two well-known examples well support the excitement for the opportunities of ICTs as applied to Citizen Science: FoldIt<sup>6</sup> and Galaxy Zoo<sup>7</sup> are completely internet-based projects asking for non-experts' participation (Wynn, 2017). Both websites propose tasks to be performed by Internet surfers directly on the web. FoldIt, a project developed by

the University of Washington, proposes folding puzzles about complex molecules in order to develop new protein structure models for lab testing and extract proteins' morphological configurations (ibid). Galaxy Zoo has a similar aim to perform long tasks more rapidly, but calls for users to classify large collections of images of galaxies, identifying objects. The initiatives were, and still are, quite successful: FoldIt users helped research in protein design, creating new structures from scratch (Koeppnick et al., 2019); Galaxy Zoo went beyond expectations as participants classified several thousands of images of galaxies in such a short time that the project went through many editions and became a stable project in the transnational community of astronomers (Clery, 2011).

The success of those projects fostered similar opportunities to develop web applications that promote crowd-sourcing of data (Haklay, 2013) through mobile apps or other devices. This brings us back to environmental monitoring, the main area considered in this review. Safecast<sup>8</sup> and iNaturalist<sup>9</sup> are both well-known and celebrated global projects dedicated respectively to radiation mapping and biodiversity monitoring. In these two cases, ICTs are crucial, although in different ways: rather than turning to the public to make sense of massive unexplored data sets, Safecast and iNaturalist asks for contributions to collect original data. A key condition is to use specific channels developed by the two projects. The Safecast project provided tutorials for DIY Geiger counters, also making kits available to build an already validated tool (the bGeige Nano), while iNaturalist requires the use of its app to collect georeferenced pictures of species. The control of data provided by non-experts that volunteer in these projects is crucial: data need to be validated in order to contribute to populating a consistent and reliable data set. Validation procedures are obligatory passage points: first and foremost for Citizen Science as an institutional research practice to become 'widely accepted as a valuable research tool' (Bonter & Cooper, 2012, p. 305). Data produced by amateurs, as recalled earlier, is susceptible to stigmatisation (Conrad & Hilchey, 2011). Therefore, data quality in Citizen Science is absolutely a serious topic to be planned ex-ante, checked ex-post, and even controlled during data collection (Balázs et al., 2021). Digital technologies provide support for this: apps may ensure that the data is transmitted safely as well as providing the opportunity for georeferenced data. Besides supporting data richness, ICTs further allow other practices useful for data validation through specific scripts of interaction (called protocols; Van Dijck, 2013) with the data collection infrastructure. The design of practices of data sharing between non-users and the project may support specific objectives. Safecast aims to collect radiation and air pollution data to create a global map: accordingly, project promoters set-up specific requirements for data uploading that blocks attempts at unsatisfactory data. This assures a first level of data quality. iNaturalist as a platform relies on community data validation: any report uploaded to the platform can be validated by other members of the community, directly confirming or disconfirming the identification online. In this sense the scripts of interaction have proceduralised data validation, configuring the community as service-provider (He & Wiggins, 2015). The community contribution also presents opportunities for preserving engagement (Mahr & Dickel, 2019). Members of online communities of amateurs that contribute by identifying species or reporting events are accessing platforms that borrow social media features such as forums, direct messaging, customisation of profiles, badges, and scores and ranks for users. Taken as a whole, these techniques of gamification are encouraged to keep participants contributing to the projects as well as producing interaction among them (Glas & Lammes, 2019; Skarlatidou & Haklay, 2020).

Finally, ICTs enable opportunities to represent phenomena, offering alternative ways of visualisation. Two examples stand out from the literature because of the effective responses to two extremely serious accidents in early 2010s. The case of Safecast perfectly exemplifies the integration with other collaborative projects such as OpenStreetMap: Safecast plotted crowd-data about radiation in the Fukushima Daiichi prefecture, showing the concentration of radiation in the aftermath of the accident at the nuclear plant. Those maps, which are being continuously updated, were helpful in limiting the exposure of the population, covering a blind spot of the official authorities (Wynn, 2017). A second example is the balloon mapping by the Louisiana Bucket Brigade<sup>10</sup> in the United States: during the oil spill crisis in the Gulf of Mexico, volunteers took aerial pictures with cameras tied to helium balloons or kites. These pictures were then released online to provide information about the state of the oil spill (Anderson, 2014; McCormick, 2012).

This stronghold of ICTs applied to crowd-data is largely celebrated in Citizen Science: ICTs are portrayed as a trigger for enlarging participation, addressing some critical issues connected to the need of scientific accuracy such

as data validation, and in some cases of crisis they demonstrate the potential subversion of regimes of authority connected to environmental monitoring. At the same time ICTs provide the infrastructure for technologies of participation for the masses, making possible their reproduction at different scales.

Nonetheless, the celebration of technology in the participation and engagement of non-experts require some critical reflections about how this participation and engagement are promoted and performed in practice through the mediation of technologies. Indeed, it would be partial and misleading to consider only the bright side of ICTs. Here again, the STS literature might be of some help: research into ICTs, algorithms, and digital platforms has highlighted how technical choices embed assumptions and perspectives on users as non-neutral technologies (Gillespie, 2014; Van Dijck et al., 2018). Criticism about the configuration (Mackenzie, 2006) of online users through protocols (Van Dijck, 2013) as well as accusations about exploiting unpaid labour through platforms (Gandini, 2021) apply also in the case of Citizen Science platforms and related online portals; Mahr and Dickel (2019) critically consider how data collection by non-experts is actually a sort of unpaid labour with some consequences, undermining the promises for democratisation and opportunities for the openness of technoscience (Mirowski, 2018). Also international surveys reported how main activity for non-experts invited to join Citizen Science project consist in accomplishing tasks for data collection, often through dedicated apps (Giardullo et al., 2023; Hecker et al., 2018) Although they enable processes of participation under certain conditions, ICTs can be part of a reiterated distancing between experts and non-experts. Most recent research on Citizen Science digital platforms has dealt with the use of data collected by non-experts (Giardullo, 2022; Ponti et al., 2022): many Citizen Science platforms use data to train machine learning algorithms for automated classification of data. Intersecting with the current trend towards artificial intelligence, Citizen Science can provide a great amount of training datasets that allow optimisation of automated classification systems (e.g. about animal species); the participation of non-experts consist in being part of a loop feeding machine learning algorithms, thus reducing participation to an ancillary though necessary component (Ponti et al., 2022). Conversely, in the long run, the contribution of non-experts may become accessory in specific domains once the automated classification systems are trained. Is participation in Citizen Science facing the same risk of low-specialisation work creating a cleavage between unskilled and skilled volunteers?

This is a potentially relevant research question for the development of participatory knowledge creation processes.

## 6 | CONCLUSION

This review started by bringing to readers' attention the need to reflect on the issue of non-expert participation into technoscientific knowledge creation, as we are at the peak of the trajectory of formal invitations by experts to engage with scientific knowledge creation. As shown, EU and U.S. research policies are pushing for an agenda of inclusion as a key opportunity to deal with global challenges.

Against this background, the review articulated three main foci: the demarcation between experts and non-experts, Citizen Science as a response to the failures connected to such a demarcation, and finally the enabling role of digital technologies in supporting the participation of non-experts. The review developed an overview across different examples from different experiences, highlighting both grassroots and top-down engagement of non-experts in research activities.

To conclude this review, it may be helpful to better express the connection between the three foci and suggest potential research areas for sociology and STS.

So far, data has emerged as a recurrent element and possibly the most promising, since the demarcation of boundaries, a key process in expert and non-expert relationship, seems to hinge around data. The report 'Science, the endless frontier' by Bush (1945) depicts a social order based on a clear cut between experts and non-experts: apparatuses for technoscientific research in connection with decision-making (Waterton & Wynne, 2004) and the power of institutions of knowledge co-create the definition of official experts entitled to provide, interpret, and

disseminate data. Data are crucial as a key certification of authority. Indeed, data contribute to a process of demarcation; by this I mean not only the aggregation of elements of information but the process of collecting evidence of a given context and situation. As reconstructed in this review, this is at the core of such a demarcation process or boundary work (Gieryn, 1999) between scientists and non-experts. Scientific institutions have based their authority on the monopoly of data collection according to tools and methodologies and professional seriousness in conducting field work, sometimes even banning alternative sources (Aronova, 2017) or not accepting them (Berti Suman & Van Geenhuizen, 2019). Hence, often data creation is a field of contestation; specific communities or areas affected by environmental stress take the burden of proving their condition, creating data that were not available (Allen, 2018; Corburn, 2005; Gabrys, 2016, 2022; Irwin, 1995; Wynn, 2017).

In reflecting about digital technologies for non-experts' participation in Citizen Science, we can consider a move across levels. The rise of ICTs includes both portable devices and the infrastructures that allow their proper functioning. Non-experts' participation has enjoyed both; mobilising the category of invited participation from Mahr and Dickel (2019), it has been possible to consider both grassroots projects that developed their own infrastructures of data collection, validation, and dissemination (e.g. Safecast, Louisiana Bucket Brigade) providing alternative representation of environmental crises as well as massive crowdsourcing projects for biodiversity monitoring (e.g. iNaturalist). However, besides opportunities of digital participation, as the STS literature shows, the limits and risks of specific configuration of those technologies should be considered as well. As argued by Bulkeley and Mol (2003), considering current ICT-enhanced opportunities for participation, the issue now is how participation is configured. Further elaborating on the classic STS literature on scripts (Akrich, 1992) and the configuration of users (Mackenzie, 2006; Woolgar, 1990), for our current datafied society (Van Dijck et al., 2018), other debates may be crucial to make sense of technologically enhanced participation in technoscience. ICTs work as enablers of participation in quantitative terms for sure, nonetheless they can set new conditions and more nuanced, if not ambiguous, effects. Critical data studies (Iliadis & Russo, 2016) and platform studies (Plantin et al., 2018), which focus on the use and construction of data and patterns of interaction, may offer their support in engaging with research on participation, borrowing data and connected practices as a useful research object to also address the ethical implications of certain conditions for participation.

## CONFLICT OF INTEREST STATEMENT

The author declares that no conflict of interest exist.

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## ENDNOTES

- <sup>1</sup> As brilliantly synthesised by Medin and Bang (2014) the term 'public' is not neutral, rather 'is itself distancing and tends to homogenise the recipients of science communication. In our community-based research we have been impressed with the wide diversity of experience, expertise, and perspectives within our communities' (p. 13625).
- <sup>2</sup> This is a quite common case that may happen, in spite of the UNECE convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (1998) so called Aarhus convention that recognises and sets up the rights of access to information, public participation in decision-making and access to justice in environmental matters states (Fasoli & McGlone, 2018)
- <sup>3</sup> The Lisbon Agenda refers to 'publics'. However, the concept of the 'public' itself does not reflect the whole complexity of non-experts: indeed, in this 'engagement turn' we have seen a shift from a dialogical approach (Bucchi, 2008) to the open request by institutions to engage citizens in supporting the creation of scientific knowledge, moving the idea of communication between science and society to an higher level. For a typology see Irwin, 2008.
- <sup>4</sup> For example, global radiation maps such as Safecast ([safecast.org](https://safecast.org)) or global biodiversity monitoring projects such as iNaturalist ([inaturalist.org](https://www.inaturalist.org)). I will return to both cases in the next paragraph.
- <sup>5</sup> Irwin in his book considered Citizen Science to be a synonym of 'popular epidemiology'. He has not been even the first one in using the label 'Citizen Science' as showed by a discussion on Zooniverse's blog (see

<https://www.zooniverse.org/talk/15/58862>) which can be tracked back to 1979, but certainly he contributed in popularising the broad concept of non-experts dealing with the production of scientific data.

<sup>6</sup> [fold.it/portal/](http://fold.it/portal/).

<sup>7</sup> [zooniverse.org/projects/zookeeper/galaxy-zoo/](http://zooniverse.org/projects/zookeeper/galaxy-zoo/).

<sup>8</sup> [map.safecast.org](http://map.safecast.org).

<sup>9</sup> [inaturalist.org](http://inaturalist.org).

<sup>10</sup> [labucketbrigade.org](http://labucketbrigade.org).

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