Citizen Science in Central and Eastern Europe

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Content

Citizen Science in the 21st century

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Citizen science occupies an increasingly prominent position in contemporary research practice, yet its growth has been uneven, context-dependent, and shaped by diverse disciplinary needs rather than by a single coherent movement. The term encompasses a broad range of activities through which members of the public contribute to or collaborate in scientific research, overlapping with related concepts such as community science, participatory monitoring, and volunteer-based research (Shirk et al., 2012; Eitzel et al., 2017). Although these activities share certain principles, such as the involvement of non-professionals in knowledge production, they differ significantly in purpose, structure, and scope. Today, citizen science functions less as a unified paradigm and more as a family of related approaches responding to various scientific, social, and institutional developments (Haklay et al., 2021; Kullenberg and Kasperowski, 2016). Several factors explain why citizen science has gained traction in recent years. Advances in digital technology have enabled large-scale data collection and online collaboration, lowering barriers to participation and facilitating distributed observation, annotation, and analysis (Newman et al., 2012; Dickinson et al., 2012). Simultaneously, open science policies have increased attention to transparency, accessibility, and public engagement in research, creating institutional support for new forms of involvement (Fecher and Friesike, 2014; Ignat and Ayris, 2020). In addition, many scientific domains face practical constraints that citizen participation can help address, particularly where extensive geographical coverage or long-term monitoring is required. The result is not a uniform shift in research practice but a gradual expansion of participatory approaches across a widening range of disciplines and policy arenas, including contributions to monitoring progress towards the Sustainable Development Goals (Fritz et al., 2019, Fraisl et al., 2020).

Historical perspectives are important for understanding this development. Public involvement in science is not new; amateur naturalists contributed to taxonomy, botany and ornithology throughout the nineteenth century, sometimes producing work comparable to that of professional scientists (Cooper et al., 2007; Miller-Rushing et al., 2012). What distinguishes current practices are their scale, formalisation, and the presence of explicit discourse around participation and governance. In the 1990s, two influential conceptualisations helped shape the field. Bonney and colleagues framed citizen science as a structured research method in which volunteers assist scientists by collecting data according to predefined protocols (Bonney et al., 2009). This model emphasised methodological clarity, efficiency, and the value of volunteer labour for large-scale inquiry. In contrast, Irwin (1995) argued that citizen science concerns the relationship between science and society more broadly, complementing wider work on public engagement and co-production (Jasanoff, 2003; Callon et al., 2001). He stressed that scientific knowledge is embedded in social contexts and that public engagement is necessary to ensure responsiveness to local concerns and democratic accountability (Jasanoff, 2003). These two lineages, one rooted in practical data-gathering needs, the other in reflexive understandings of science–society relations, continue to shape the field. Many citizen science projects today clearly follow the contributory model described by Bonney et al., relying on large numbers of volunteers to record species observations, submit environmental readings, or classify images (Bonney et al., 2016). Other projects, particularly in health, environmental justice, cultural heritage, and the social sciences, draw more heavily on Irwin's vision and on critical perspectives that foreground power and equity. These projects involve citizens in framing questions, interpreting results, or negotiating research priorities, sometimes explicitly linking participation to advocacy or regulatory debates (Ottinger, 2010; Dawson, 2018). Rather than representing competing understandings, these models illustrate how heterogeneous citizen science has become and how different disciplines mobilise public participation for different purposes (Shirk et al., 2012; Eitzel et al., 2017).

This heterogeneity complicates efforts to define the field. Narrow definitions that restrict citizen science to data collection do not adequately represent participatory research in the humanities, local environmental activism, or community-led investigations (Haklay, 2013; Kullenberg and Kasperowski, 2016). Conversely, definitions broad enough to encompass all public involvement risk losing analytical precision and obscuring important differences between consultation, collaboration, and co-creation (Eitzel et al., 2017; Shirk et al., 2012). For this reason, organisations such as the European Citizen Science Association have moved from prescriptive definitions to flexible characteristics that describe common features while allowing for disciplinary variation (ECSA, 2015; ECSA, 2020; Haklay et al., 2020). This approach reflects the pragmatic reality that citizen science is shaped as much by institutional, cultural, and technological contexts as by epistemic ones (Hecker et al., 2018; Vohland et al., 2021). Libraries provide a clear example of this context dependence. Their participation in citizen science initiatives has grown steadily, but the forms this involvement takes differ across public, academic, national, and research libraries (Ayris and Ignat, 2018, Mumelaš et al., 2025). Public libraries often facilitate participation through community programmes, lending equipment such as radon detection kits, or hosting events related to local environmental monitoring (Stanifer et al., 2024; Vandegrift and Varner, 2013). Academic and research libraries support citizen science by providing data management expertise, training, and open science infrastructure, aligning their services with institutional strategies for public engagement (Ayris and Ignat, 2018; Mumelaš et al., 2025). In cultural heritage settings, libraries coordinate large-scale transcription, annotation, and digitisation efforts, relying on citizen contributions to improve access to historical materials (Holley, 2010; Ridge, 2014; Dunn and Hedges, 2012). These examples demonstrate that libraries are not merely peripheral supporters but increasingly function as intermediaries connecting research institutions with diverse publics.

Despite these opportunities, citizen science presents several challenges that require careful consideration. Designing studies that are both accessible and methodologically robust can be difficult. Data collected by volunteers may vary in quality due to differences in training, equipment, or interpretation, necessitating clear protocols, calibration procedures, and validation mechanisms (Wiggins et al., 2011; Kosmala et al., 2016; Stevenson et al., 2021). Ethical considerations are equally important. Projects must address privacy, informed consent, data protection, and the potential for unintended consequences, especially when dealing with sensitive information or vulnerable communities (Resnik et al., 2015; Bowser et al., 2017; Phillips et al., 2014). Without thoughtful design, participatory initiatives risk becoming extractive, benefiting institutions more than participants, or reinforcing existing inequalities (Senabre Hidalgo et al., 2021; Tauginienė et al., 2020; Dawson, 2018). Evaluating citizen science introduces additional complexity. Scientific impact can be measured through publications, datasets, or contributions to monitoring systems, but other effects, such as learning, behavioural change, community cohesion, or cultural value, require qualitative or mixed-method approaches (Bonney et al., 2016; Phillips et al., 2018). Frameworks developed by Kieslinger et al. (2018) and Bornmann (2013) emphasise multidimensional evaluation, recognising that citizen science generates a range of outcomes that cannot be captured by single indicators. Evaluation is not only retrospective but also important for project planning, helping researchers articulate goals, anticipate limitations, allocate resources effectively, and increasingly link project design to policy agendas such as the Sustainable Development Goals (Fraisl et al., 2020; Fritz et al., 2019).

Given these considerations, citizen science is best understood not as a single methodology but as a set of practices shaped by disciplinary norms, institutional structures, available technologies, and participant motivations (Hecker et al., 2018; Vohland et al., 2021). Its contribution lies in the range of possibilities it offers for collaboration, knowledge production, and public engagement, rather than in any universal promise of transformation. The field continues to evolve as new tools, infrastructures, and policy environments develop, and as institutions such as libraries experiment with ways to integrate participatory research into their services.

Participation and Citizen Science

Citizen science projects vary widely in how they involve members of the public, and understanding this variation is essential for interpreting what these projects can achieve and how they should be designed (Shirk et al., 2012; Haklay, 2013; Hecker et al., 2018). Participation is not a single act, but a spectrum of roles shaped by disciplinary conventions, institutional constraints, and the expectations of both researchers and citizens (Shirk et al., 2012; Vohland et al., 2021). Early work in the field focused on identifying discrete categories along this spectrum, producing typologies that link forms of participation to different rationales and project designs (Bonney et al., 2009; Shirk et al., 2012; Eitzel et al., 2017). Although these frameworks differ in terminology and emphasis, they serve a similar purpose: to clarify how labour, knowledge, and decision-making are distributed within participatory research. They also provide a basis for evaluating whether participation is appropriate to a project's goals and whether participants have the opportunity to make meaningful contributions, including in areas such as education and public health (Jordan et al., 2011; Den Broeder et al., 2018). One of the most established models is from Bonney and colleagues, who distinguished between contributory, collaborative, and co-created projects (Bonney et al., 2009; Bonney et al., 2016). In contributory projects, still the most common form, professional researchers design the study and define the data requirements, while citizens primarily gather observations or complete structured tasks (Bonney et al., 2009; Dickinson et al., 2012). This model has proved effective for large-scale environmental monitoring and observational science, where distributed data collection is essential and a high level of standardisation is required. The collaborative model describes projects in which volunteers participate in additional phases, such as refining research questions, analysing data, or contributing to interpretation (Shirk et al., 2012). Co-created projects go further, involving citizens and scientists jointly throughout the entire research process. While less common in large-scale studies, co-created approaches are well suited to local or community-driven inquiries where scientists and citizens have shared stakes in the outcomes and where redistribution of decision-making power is an explicit goal (Tauginienė et al., 2020; Ballard et al., 2017). Shirk et al. (2012) expanded this model to include contractual and collegial forms of participation. Contractual projects begin when communities identify a problem and seek scientific expertise to address it. In these cases, the public initiates the inquiry, and researchers act as facilitators or consultants, a pattern also observed in "popular epidemiology" and community-based environmental health work (Brown et al., 2012). Collegial projects, by contrast, recognise that non-professionals can conduct research independently, producing knowledge that may or may not be integrated into academic science (Haklay, 2013). These categories make explicit what is often implicit in participatory work: participation is not always invited from above but sometimes emerges from below, driven by local concerns, personal interests, or community priorities (Ottinger, 2010). The distinction is particularly relevant in contexts such as environmental justice, cultural history, or public health, where communities mobilise scientific tools to address issues of direct relevance to their lives (Corburn, 2005; Dawson, 2018). Although useful, these classifications should not be interpreted as strict boundaries. Many projects combine elements from different categories, and participation often shifts over time as volunteers acquire skills or as new opportunities for engagement arise (Kieslinger et al., 2018). The richness of citizen science lies partly in this flexibility. For example, a project may begin with a contributory model to collect baseline data but later incorporate collaborative elements as volunteers become familiar with the subject. Moreover, participants bring varied motivations, ranging from a desire for learning and enjoyment to personal concern for environmental or social issues (Jordan et al., 2011). These motivations influence not only how people engage but also how participation can be supported and sustained, with implications for learning outcomes and self-efficacy (Phillips et al., 2018; Ballard et al., 2017).

The relationship between participation models and expected contributions can also be examined through the nature of the tasks involved. Many citizen science activities rely on relatively simple, rule-based interactions such as identifying species, classifying images, or transcribing text (Newman et al., 2012; Wiggins and Crowston, 2011). These tasks require consistency and scale rather than specialised expertise, although volunteers often develop expertise over time. In cultural heritage and library contexts, citizen science tasks commonly involve transcription, annotation, metadata creation, or the enhancement of digital collections (Holley, 2010; Ridge, 2014). Such tasks allow members of the public to engage deeply with historical material while simultaneously contributing to scholarly research and collection enhancement. They also demonstrate how citizen science intersects with digital humanities, where collaborative knowledge production is already well established (Terras, 2016; Causer and Terras, 2014). Other participatory models involve more interpretive or creative work. Community-led environmental monitoring may require volunteers to observe changes in local habitats, identify potential causes for these changes, or contribute to designing data collection strategies (Fraisl et al., 2020). In health-oriented projects, participants may help formulate questions about environmental exposures or public health risks, drawing on local knowledge or lived experience (Den Broeder et al., 2018). These forms of participation blur the line between scientific and experiential expertise and reflect broader debates about whose knowledge is valued in research (Irwin, 1995; Jasanoff, 2003). They also highlight the importance of context: a project focused on biodiversity monitoring in a national park may have very different participation dynamics from an urban air quality project led by community activists (Kimura and Kinchy, 2016). The distribution of tasks has methodological implications. Projects that rely on simple, repetitive tasks must ensure accessibility, clarity, and consistency. Design choices, such as the presentation of instructions, the structure of interfaces, and the provision of examples, affect data quality and participant experience (Wiggins et al., 2011; Kosmala et al., 2016). In these cases, researchers often standardise methods, provide training materials, and implement validation mechanisms to minimise errors (Stevenson et al., 2021; Balázs et al., 2021). In contrast, co-created or interpretive projects require deliberative processes, iterative discussion, and negotiation of priorities. Here, participation becomes more relational, and the success of the project depends on trust, communication, and shared ownership rather than technical standardisation (Bonney et al., 2016; Senabre Hidalgo et al., 2021; Kieslinger et al., 2018).

Understanding participation also requires attention to the institutional and social environments in which projects take place. Libraries, for example, support a wide range of participatory activities, but do so within frameworks shaped by educational missions, public service goals, and resource constraints (Ayris and Ignat, 2018). Public libraries may focus on activities that support community engagement, digital inclusion, or local history, while academic libraries may integrate citizen science into open science services or research support infrastructures (Pandey et al., 2020; Vandegrift and Varner, 2013). In both cases, the type of participation encouraged is influenced by institutional priorities and the resources that can be devoted to the work (Hecker et al., 2018; Ryan et al., 2018). This institutional perspective highlights an important, sometimes overlooked, aspect of citizen science: participation is not only a relationship between individuals and scientific projects, but also between institutions and communities (Hecker et al., 2018; Vohland et al., 2021). The roles and expectations of participants are shaped by how institutions frame the project, communicate its goals, and organise its activities (Fraisl et al., 2023; Skarlatidou and Haklay, 2020). For example, a library-led transcription initiative may emphasise learning, cultural heritage, and community identity, while a university-led environmental project may emphasise data accuracy, standardisation, and scientific outcomes. The framing affects who participates, how they engage, and what they consider meaningful contributions (Bonney et al., 2016; Dawson, 2018).

The temporal dimension of participation is equally important. Some citizen science initiatives require sustained engagement over long periods, such as repeated biodiversity surveys or multi-year environmental monitoring. Others involve episodic or short-term involvement, such as one-off digitisation events or seasonal data campaigns (Dickinson et al., 2012; Newman et al., 2012). The sustainability of participation depends on the alignment between project demands and volunteer capacity, the availability of support structures, and the presence of meaningful feedback (Phillips et al., 2018; Jennett et al., 2016).

Volunteers are more likely to remain engaged when they see the value of their contributions, receive timely updates on project progress, and feel connected to the broader purpose of the work (Robinson et al., 2018; Jennett et al., 2016). This creates a feedback loop: well-designed participation fosters motivation, which in turn supports data quality and project continuity.

While typologies are useful for mapping the field, they do not fully capture the informal or emergent forms of participation that arise spontaneously. Social media platforms, for example, enable ad hoc sharing of observations, images, or local knowledge, sometimes outside formal project structures (Newman et al., 2012). These contributions may be incorporated into research, raising questions about what counts as citizen science and how boundaries between formal and informal participation should be defined (Eitzel et al., 2017; Skarlatidou and Haklay, 2020). Similarly, some community-led initiatives do not use the term "citizen science" at all, yet their activities involve systematic observation, data collection, or interpretation (Kimura and Kinchy, 2016; Corburn, 2005). These examples further highlight that participation in science often extends beyond named projects and institutional frameworks.

Taken together, these perspectives show that participation in citizen science is multi-layered and context-dependent. Its forms are shaped by task structures, disciplinary norms, participant motivations, institutional environments, and the histories of the communities involved (Hecker et al., 2018; Vohland et al., 2021; Fraisl et al., 2023). Participation frameworks provide a vocabulary for describing this diversity, but they should not be used prescriptively. Instead, they serve as tools for reflection, helping researchers and institutions design activities that are appropriate, ethical, and aligned with project goals (Shirk et al., 2012; Den Broeder et al., 2018). They also help clarify expectations for participants, enabling them to understand their roles and the potential significance of their contributions. The next important area of citizen science research is addressing methodological considerations. While participation structures describe who is involved and in what capacities, methodological frameworks outline how citizen science projects are organised, how data are produced, and what types of infrastructures and governance arrangements are needed to support them (Hecker et al., 2018; Skarlatidou and Haklay, 2020). Methodology influences not only scientific outcomes but also participant experience, ethical robustness, and the long-term sustainability of citizen science (Kieslinger et al., 2018; Ryan et al., 2018).

Methodological Considerations: Designing and Sustaining Citizen-Science Practice

Methodology in citizen science is shaped by the need to coordinate contributions from individuals who differ widely in expertise, interests, time availability, and digital skills (Hecker et al., 2018; Vohland et al., 2021). Unlike laboratory research, where conditions are tightly controlled, citizen science projects occur across distributed environments such as homes, public spaces, online platforms, and community institutions, creating methodological challenges that require flexibility and adaptation (Haklay, 2013). These challenges must be addressed through careful planning, iterative design, and ongoing support, directly affecting both data quality and participants' sense of efficacy and engagement (Kosmala et al., 2016; Jennett et al., 2016). Because citizen science merges scientific goals with public engagement, methodological design must balance rigour, accessibility, and ethical responsibility (Hecker et al., 2018; Tauginienė et al., 2020).

A defining feature of citizen science methodology is its iterative nature. Many projects start with modest pilot phases in which researchers test protocols, digital tools, and instructions, using volunteer feedback to refine methods (Haklay, 2018; Jennett et al., 2016; Kosmala et al., 2016). An iterative approach and rapid prototyping are especially important for technology-enabled projects and for engaging under-represented or digitally less experienced participants (Haklay, 2018). As projects expand or reach new participant groups, further adaptations are often necessary, reflecting a pragmatic commitment to responsiveness and context (Vohland et al., 2021). Effective citizen science practice often depends on training to support both research-quality outcomes and participant confidence (Jennett et al., 2016; Tauginienė et al., 2020). This also includes the institutional support required for long-term project sustainability. Libraries are particularly well placed for digital upskilling, information literacy training, and providing the community infrastructure essential for sustained engagement (Ayris and Ignat, 2018; Mumelaš and Martek, 2024). Research on citizen labs and similar initiatives shows that local contexts and partnerships are vital for scaling up and making capacity building more inclusive.

Data collection in citizen science must prioritise clarity, compatibility, and quality assurance. Researchers typically develop detailed protocols to standardise data gathering, clarify instructions, set boundaries for acceptable variation, and promote multimodal communication (Kosmala et al., 2016;

Stevenson et al., 2021; Haklay et al., 2021). Data-validation mechanisms such as expert review, algorithmic checks, and triangulation across contributors further enhance reliability; their design depends on whether the data are observational, sensor-based, or text-based (Kosmala et al., 2016; Stevenson et al., 2021). Crowdsourced annotation and transcription projects frequently use staged review or peer evaluation to ensure high quality (Holley, 2010). Digital infrastructure, especially user-friendly and accessible interfaces, is now central to participatory science (Hecker et al., 2018; Kosmala et al., 2016). Web-based, mobile, or dashboard platforms not only support participation but also provide communication, feedback, and community-building, making achievements visible and supporting retention (Jennett et al., 2016; Holley, 2010). Ethical and data-governance demands are increasing. Citizen science data should follow FAIR principles (findable, accessible, interoperable, and reusable), but this must be balanced with respect for contributors' privacy and autonomy, especially in projects dealing with health, environmental, or geolocated data (Tauginienė et al., 2020; Senabre Hidalgo et al., 2021). Securing informed consent, anonymisation, and clear licensing are essential practices, for which libraries and trusted community partners are often critical facilitators (Ignat and Ayris, 2020; Mumelaš and Martek, 2024).

Participant management methods must align with the participation model and project goals. Recruitment, communication and support are essential throughout the project cycle, as are strategies tailored to either large, contributory projects (such as open public calls or partnerships) or small-scale, co-created studies (Haklay, 2013; Robinson et al., 2018). Retention, motivation and recognition depend on feedback, community building and visible impact (Jennett et al., 2016; Robinson et al., 2018). Ethics also require recognising and addressing power differentials. Extractive models that disregard volunteer input are increasingly critiqued, and best practice involves mechanisms for real agency, shared decision-making and recognition (Senabre Hidalgo et al., 2021; Tauginienė et al., 2020). Long-term sustainability is more likely when projects are embedded in institutions such as libraries, enabling continuity across funding cycles, and when protocols, documentation and governance are open and transparent (Ayris and Ignat, 2018; Mumelaš and Martek, 2024). Rigorous, responsive methodology shapes both the scientific and social outcomes of citizen science. The long-term value– scientific, educational and communal – depends on adaptive experimentation, quality assurance and genuine partnership with participants (Hecker et al., 2018; Vohland et al., 2021; Tauginienė et al., 2020).

Evaluation, Evidence and the Question of Impact

Evaluating citizen science is essential for understanding what these projects achieve, how they compare to other research methods, and how they contribute to broader scientific and societal objectives (Kieslinger et al., 2018; Roche et al., 2020). Despite the importance of evaluation in contemporary research governance, citizen science projects vary widely in how they are assessed. This variation arises from the heterogeneity of the field: projects operate at different scales, pursue different goals, use different types of data, and engage participants in various ways. Consequently, evaluation cannot rely on a single set of metrics. Instead, it requires a pluralistic approach that recognises the diversity of outputs and outcomes that citizen science can produce, including scientific, educational, behavioural, cultural, and community effects (Kieslinger et al., 2018; Phillips et al., 2018; Auerbach et al., 2019; Tauginienė et al., 2020). Evaluation frameworks must therefore accommodate scientific, educational, cultural, and community dimensions, while acknowledging that not all projects aim to achieve all forms of impact (Wehn et al., 2021). The challenge is to design evaluation strategies that are both feasible and sensitive to project-specific characteristics, and to integrate them into planning from the outset rather than adding them retrospectively.

Scientific evaluation often focuses on data quality because concerns about reliability have traditionally shaped perceptions of citizen science. For many years, scepticism about public participation centred on the belief that non-professionals might produce inconsistent or inaccurate data. However, research increasingly shows that volunteers can generate high-quality contributions when supported by clear protocols, training materials, and validation mechanisms (Kosmala et al., 2016; Wiggins et al., 2011; Stevenson et al., 2021). The rigour of data produced in citizen science is influenced by several factors: the clarity of sampling instructions, the usability of data-collection tools, the presence of calibration procedures, and the extent to which projects incorporate verification steps (Kosmala et al., 2016). Some initiatives use multiple volunteers independently assessing the same phenomenon to identify discrepancies, while others rely on expert review or algorithmic tools to flag anomalous data (Danielsen et al., 2014). This combination of methodological design and quality-control practices allows citizen science data to be used reliably in ecological monitoring, biodiversity assessments, cultural heritage analysis, and other fields requiring structured inputs. Scientific impact is not limited to data quality. Many citizen-science projects contribute to peer-reviewed publications, improve datasets used in long-term monitoring programmes, or generate tools and protocols that support future research (Cooper et al., 2014; Auerbach et al., 2019). In cultural-heritage contexts, large-scale manuscript transcription initiatives produce annotated corpora that enable new forms of historical, linguistic or archival analysis (Holley, 2010; Ridge, 2014). These contributions illustrate that citizen science can support both incremental and transformative research outcomes. However, the value of these outputs depends on how well they are documented, curated and integrated into institutional or disciplinary infrastructures. Without adequate documentation, even high-quality datasets may have limited long-term utility. This is why many institutions, including libraries, play an important role in ensuring that data adhere to FAIR principles (Shirk et al., 2012). FAIR-compatible data management increases the likelihood that citizen-science outputs will be preserved, shared and used beyond the lifespan of individual projects.

Another dimension of evaluation concerns participants' experiences. Citizen science is often justified partly by its educational benefits, but these benefits cannot be assumed. Projects vary considerably in how much they support learning, facilitate skill development, or deepen public understanding of scientific processes. Studies indicate that well-designed initiatives can enhance scientific literacy, foster critical thinking, and encourage sustained interest in scientific topics (Jordan et al., 2011; Bonney et al., 2016; Roche et al., 2020). Engagement with data collection or analysis provides opportunities for volunteers to learn about research methods, disciplinary concepts, or broader environmental and social issues. However, learning does not occur automatically; it is more likely when projects provide adequate explanations, contextual information, and opportunities for reflection, supported by embedded assessment and explicit learning goals (Phillips et al., 2014; Phillips et al., 2018; Falk et al., 2012). In this respect, libraries are often effective facilitators because they are already equipped to support structured learning environments and provide educational materials to participants (Ayris and Ignat, 2018; Mumelaš and Martek, 2024). Behavioural and psychological impacts are also relevant. Participation may foster a sense of agency, enabling individuals to feel they can contribute meaningfully to research or community decision-making, and may encourage more sustainable behaviours or conservation actions in environmental contexts (Bonney et al., 2016). In environmental and health-related projects, involvement can increase awareness of ecological or public health issues, influence attitudes, and sometimes support changes in everyday practices (Den Broeder et al., 2018). This type of impact is difficult to measure, often requiring self-report surveys, interviews, or longitudinal studies (Phillips et al., 2018; Auerbach et al., 2019). Recent work has also highlighted links between participation, connection to nature, and mental wellbeing, suggesting that citizen science activities can have psychological benefits in addition to cognitive and behavioural ones (Beatty et al., 2025). Nonetheless, even where formal evidence is limited, many volunteers report a greater sense of connection to scientific processes and a heightened interest in the issues addressed by the project.

Social and community impacts are more diffuse but can be significant. Some citizen-science projects strengthen community networks, especially where participation is organised through local institutions such as libraries, schools or community centres (Corburn, 2005; Kimura and Kinchy, 2016). Group monitoring events, transcription meetups or community workshops create opportunities for social interaction and collective learning. In areas affected by environmental hazards, citizen science can empower communities to gather evidence, articulate concerns and engage with policymakers (Den Broeder et al., 2018; Haklay, 2018). For example, library-lending programmes involving radon detection kits not only provide equipment but facilitate community discussions about health risks and environmental awareness (Stanifer et al., 2024). In cultural-heritage settings, crowdsourced transcription or annotation can increase public engagement with local history, strengthen connections to cultural institutions and enhance the visibility of archival materials (Ridge, 2014; Dunn and Hedges, 2012; Ting and Jeng, 2023). These forms of impact are not always easy to quantify but are essential for understanding how citizen science contributes to social cohesion and cultural value. Kieslinger et al. (2018) propose a multidimensional framework that assesses scientific, participant, and socio-ecological or socio-economic impacts, emphasising both processes and outcomes. This model recognises that effective training, ethical communication, and transparent data governance are necessary preconditions for meaningful outcomes. Similarly, Bornmann (2013) distinguishes between scientific and societal impact, arguing that different kinds of evidence are needed for each, while Auerbach et al. (2019) introduce a practical tool for planning and assessing the range of outputs produced by citizen science projects. Scientific impact may be assessed through publications, data quality, or contributions to monitoring systems, while societal impact may require interviews, case studies, media analysis, or policy tracking (Bornmann, 2013; Wehn et al., 2021). These frameworks encourage researchers to articulate evaluation strategies early in project planning, rather than treating evaluation as an afterthought, and to select indicators that align with their specific goals. Participatory evaluation offers an alternative approach. including participants, community organisations, and institutional partners in designing and interpreting evaluation processes. This approach recognises that participants may have different understandings of what constitutes success or value in a project. Engaging them in evaluation ensures their perspectives are represented and helps to avoid top-down assessments that overlook community priorities (Den Broeder et al., 2018; Wehn et al., 2021). Participatory evaluation is particularly relevant for co-created or community-led projects, where relational dynamics and shared ownership are central, and where evaluation can serve as a form of capacity building and empowerment (Senabre Hidalgo et al., 2021; Tauginienė et al., 2020).

Despite the availability of frameworks, evaluation remains challenging. One reason is that citizen science projects vary widely in scale and resources. Some are large, well-funded initiatives with dedicated evaluation teams and long-term support, while others are small, volunteer-driven efforts with limited capacity for systematic assessment (Auerbach et al., 2019; Wehn et al., 2021). Evaluation also requires expertise that not all research teams possess, especially when assessing learning outcomes, community impact, or behavioural change (Phillips et al., 2018; Roche et al., 2020). Furthermore, attributing observed outcomes to participation can be difficult. For example, changes in environmental awareness may result from participation, external events, or pre-existing interests; separating these influences requires careful study design, which may not always be feasible. Another challenge concerns the risk of relying on superficial metrics. Counting the number of participants or the volume of data collected provides some information but does not capture the depth or quality of engagement (Phillips et al., 2019; Wehn et al., 2021). Overemphasis on numerical indicators may create distorted incentives, leading projects to prioritise recruitment over meaningful involvement. Relying solely on quantitative metrics may also disadvantage projects that focus on interpretive or relational outcomes, such as cultural heritage engagement or community empowerment. A balanced approach requires combining quantitative evidence with qualitative insights that capture the nuances of participation, such as interviews, observations, or reflective exercises (Rowe et al., 2016; Roche et al., 2020). Ethical considerations also intersect with evaluation. Assessing participant experience or community impact may require collecting personal or sensitive information, which demands careful attention to privacy, consent, and fair representation (Bowser et al., 2017; Phillips et al., 2014). Furthermore, evaluation processes must avoid reinforcing inequalities. If outcomes are measured solely from an institutional perspective, the experiences and priorities of participants may be overlooked (Boucher et al., 2021; Skarlatidou and Haklay, 2020). Ethical evaluation therefore requires reflexivity: acknowledging potential biases, ensuring transparency in methodology, and respecting the autonomy and perspectives of volunteers (Senabre Hidalgo et al., 2021; Tauginienė et al., 2020).

Despite these challenges, evaluation contributes significantly to the sustainability of citizen science. Projects that demonstrate clear scientific or social value are better positioned to secure ongoing support from institutions, funders, or community partners (Hecker et al., 2018). Evaluation articulates the relevance of citizen science within broader open science and public engagement strategies, reinforcing its place within institutional landscapes (Wehn et al., 2021; Vohland et al., 2021). Libraries, in particular, benefit from evaluation because it provides evidence that citizen science services align with their missions in digital literacy, cultural preservation, and community engagement (Ayris and Ignat, 2018; Mumelaš and Martek, 2024). As a result, evaluation not only measures impact but also helps embed citizen science into long-term organisational planning. Ultimately, the role of evaluation is not merely to justify citizen science but to improve it. By identifying strengths and weaknesses in design, communication, governance, and support, evaluation provides feedback that strengthens future initiatives (Auerbach et al., 2019). Because citizen science is an evolving field, it benefits from reflective and adaptive approaches that respond to changing contexts, technologies, and community needs (Hecker et al., 2018; Roche et al., 2020). Evaluation thus functions as both a mirror and a map: it reflects what has been achieved and helps chart pathways for future development.

Conclusion

Citizen science today includes a wide range of activities involving non-professionals in scientific inquiry, shaped by local contexts, disciplinary norms, and institutional arrangements. Rather than constituting a unified paradigm, citizen science serves as an adaptable framework supporting various research goals and forms of public engagement, as reflected in evolving descriptions such as the ECSA Characteristics of Citizen Science. The preceding sections have shown how this diversity is structured: participation models describe how labour and decision-making are distributed; methodological considerations explain how projects are organised, supported, and governed; and evaluation frameworks account for the many different forms of impact that citizen science may generate. Together, these dimensions show that citizen science is as much a methodological orientation as a set of practices, linking epistemic, social, and institutional concerns.

A central theme throughout the chapter is that citizen science depends on careful design. Projects involving volunteers must balance accessibility and rigour, making scientific tasks understandable without compromising data quality – an issue highlighted in discussions of "citizen science frontiers" and human–machine systems. Achieving this balance is not straightforward; it requires iteration, testing, and the ability to adjust protocols as projects develop in response to participant feedback and contextual changes. Capacity building is equally important. Volunteers bring diverse motivations and experiences, and sustained engagement depends on clear communication, adequate training, and meaningful feedback, including embedded assessment of learning and engagement. Institutions such as libraries often play a critical role, providing infrastructure, digital literacy support, and community spaces where citizen science can take root and be sustained over time. Ethical considerations are also a key component of sustainable practice. Citizen science often relies on data collected outside controlled research environments and sometimes involves sensitive personal or environmental information, particularly in health and environmental justice contexts. Ensuring privacy, securing informed consent, managing data responsibly, and fostering equitable participation are therefore essential, especially where power relations between institutions and communities are unequal. These ethical requirements are not obstacles to participation but integral elements of responsible research design. Projects that invest in ethical communication, shared expectation-setting, and collaborative decision-making tend to build stronger relationships with participants and more durable forms of engagement.

Evaluation enables understanding of what citizen science projects achieve and how they contribute to broader scientific and societal goals. As the field is heterogeneous, evaluation must accommodate various types of evidence, from quantitative measures of data quality and scientific outputs to qualitative accounts of learning, cultural value, or community empowerment. Evaluation serves both accountability and improvement: it demonstrates impact to funders and institutions while providing insights to refine future projects, especially when integrated as embedded assessment rather than added retrospectively. For libraries and other public institutions, evaluation also strengthens the case for incorporating citizen science into long-term strategies for open science, public engagement, and community development, showing how projects align with missions related to equity, inclusion, and civic participation.

Taken together, the arguments presented in this chapter emphasise that citizen science should be understood not only as a mode of data collection, but as a collaborative process grounded in methodological design, ethical responsibility, and reflective assessment. Its value lies in the opportunities it creates for scientists, institutions, and communities to work together on issues of shared concern, producing knowledge that is both scientifically robust and socially meaningful. As the field continues to evolve, the challenge will be to sustain the balance between maintaining scientific standards and fostering accessible, inclusive participation that reflects the diversity of the public involved and addresses emerging questions about who participates, whose knowledge is valued, and how benefits are distributed.

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