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Evaluating citizen science
Towards an open framework

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Highlights

- Evaluation concepts for citizen science are required both by policy-makers, to improve citizen science funding schemes and by project initiatives, to enhance their project management.
- Citizen science programmes should be evaluated along three dimensions of participatory science: (i) scientific impact, (ii) learning and empowerment of participants and (iii) impact for wider society.
- Evaluation and impact assessment should embrace the diversity and emerging nature of citizen science.
- An open framework for evaluation can be adapted and tailored to the specific goals of citizen science programmes.

Introduction

An exponential rise in citizen science projects is currently taking place (Kullenberg & Kasperowski 2016), bringing innovation potential for science, society and policy (Holocher-Ertl and Kieslinger 2015). There are indications that citizen science contributes to transformational change in science and society through the formulation of new research questions by both members of the public and the scientific community and through the joint discovery of solutions to regional (e.g., Lee, Quinn & Duke 2006), national and even global (Theobald et al. 2015) problems of societal and scientific relevance.

As citizen science can contribute to learning about the processes of scientific enquiry and to a deeper understanding of scientific outcomes (Riesch & Potter 2014; Bela et al. 2016; Richter et al. 2016; and see Edwards et al. in this volume), it may lead to improved understanding, uptake and implementation of transparent and responsive research in society. In this way, citizen science is an approach that encourages stewardship, fosters empowerment and contributes to Responsible Research and Innovation (RRI) (Sutcliffe 2011; Wickson & Carew 2014; and see Smallman in this volume). All in all, the innovation potentials of citizen science are in line with calls for open and responsible science (European Commission 2016d).

The growing appreciation of the power of citizen science has resulted in the establishment of new funding schemes for citizen science, such as OPAL in the UK (Imperial College London 2016), the TOP CITIZEN SCIENCE programme in Austria (Zentrum für Citizen Science 2016), or the new explicit citizen science funding scheme in Germany by the Ministry of Education and Research (BMBF). Associated with this development, context-adaptable evaluation criteria are required to assess the impact of citizen science programmes on science, society and policy. Evaluation criteria are needed to inform both proper citizen science funding support and effective project management. Evaluation should assess the value of citizen science for different outcomes and/or processes. This comprises a systematic assessment of both the effectiveness and efficiency of an activity or programme against a set of explicit or implicit standards and criteria. There are two aspects to evaluation: (i) outcome-based evaluation, which assesses the overall goals of activities or programmes and the benefits to participants and recipients of the results and; (ii) process-based evaluation, which identifies the operational strengths and weaknesses of activities or programmes.

This chapter presents a framework of evaluation criteria focusing on both the process and outcome level of citizen science projects. It is an open framework for evaluating diverse citizen science initiatives, based on an in-depth review of the characteristics and diversity of citizen science activities and current evaluation practices. These are applicable for projects ranging from grassroots initiatives to those led by academic scientists. The framework incorporates the scientific, social and socio-economic perspectives of citizen science and is aligned with the Ten Principles of

Citizen Science (see Robinson et al. in this volume). The indicators developed are intended to serve as a foundation for quantitative and qualitative data collection instruments.

Citizen science evaluation

There are currently no commonly established indicators for evaluating citizen science, and individual projects have the challenge of defining the most appropriate way to collect evidence of their impact. While some experts focus on the learning gains of participants (e.g., Phillips et al. 2014; Masters et al. 2016; and see Peltola & Arpin in this volume), others concentrate on the scientific gains and socio-ecological relevance (Jordan, Ballard & Phillips 2012; Tulloch et al. 2013; Bonney et al. 2014). Haywood and Besley (2014) made a first attempt towards an integrated assessment framework by combining indicators from science education and participatory engagement. The evaluation of the scientific impact of projects is challenging, since many approaches exist and many are criticised for their shortcomings (Allen et al. 2009).

Evaluation methods demonstrating impact on individual participants are common (e.g., Brossard et al. 2005), and include aspects like gains in scientific knowledge or skills as well as wider personal impact in terms of behavioural change, interest in science, motivation and ability to participate in science (Phillips et al. 2014). Personal development of participants is an important aspect of any citizen science project but evaluation is based only on personal learning outcomes and may miss out on other important aspects, such as wider societal impact. Behavioural changes, such as taking stewardship and civic action (Crall 2010; Phillips et al. 2014), point towards an assessment of such social implications. Shirk et al. (2012) therefore recommend a more holistic approach to project evaluation, accounting for impact on scientific knowledge and individual development as well as broader socio-ecological and economic impacts. Similarly, a more comprehensive approach to evaluation might operate on three levels – individual, programme and community – and stress the potential impact of citizen science on social capital, community capacity, economic impact and trust between scientists, managers and the public (Jordan et al. 2012).

Experts advise to define learning goals and expected learning outcomes at the beginning of a project to develop an appropriate and customised evaluation strategy (Jordan et al. 2012; Phillips et al. 2014; Tweddle et al. 2012). Otherwise, project evaluation risks not properly assessing the learning gains of individuals or documenting genuine impact (Skrip 2015). The use of a variety of evaluation methods is recommended, such as pre- and post-project surveys or examination of the correspondence between participants and project co-ordinators (Bonney et al., 'Public Participation', 2009). Evaluation also has a role in adaptive project management (Wright 2011). Continuously sharing experiences and lessons learnt with all stakeholders supports the social learning process and contributes to an iterative improvement of citizen science projects and programmes. This can be supported by iterative evaluation during the course of the project, allowing for flexibility and the possibility to counteract undesirable project developments (Skrip 2015; Dickinson et al. 2012).

Despite these contributions to evaluation, citizen science projects currently lack comprehensive evaluation frameworks that would allow for comparability across projects and programmes (Bonney et al., 'Citizen Science', 2009; Bonney et al. 2014; Crall et al. 2012). A recently published evaluation rubric (Tredick et al. 2017) tries to fill this gap in citizen science programme evaluation by including the main elements found in literature, but it still remains weak on the social implications of citizen science. Citizen science stakeholders continue to seek flexible evaluation strategies that adapt to specific project contexts (Schäfer & Kieslinger 2016) and initiatives have begun worldwide to build capacity (Richter et al. in this volume), guide citizen science development (e.g., Pocock et al. 2014b; Pettibone et al. 2016) and professionalise evaluation. The European Citizen Science Association (ECSA) has taken important steps by developing Ten Principles of Citizen Science (Robinson et al. in this volume) and the framework presented here aligns with these evaluation criteria.

Developing evaluation criteria for citizen science

The evaluation criteria presented in this chapter are the result of a review of existing projects and literature, as well as qualitative analysis including stakeholder consultation, expert interviews, and iterative adaptation and additional feedback loops with stakeholders. This was led by two working groups focusing on the social sciences and natural sciences, respectively, and the evaluation criteria have undergone a circle of refinement since this work began in July 2015 (see figure 6.1).

A narrative literature review included surveying the databases Scopus, Web of Science and Google Scholar as well as the library of the

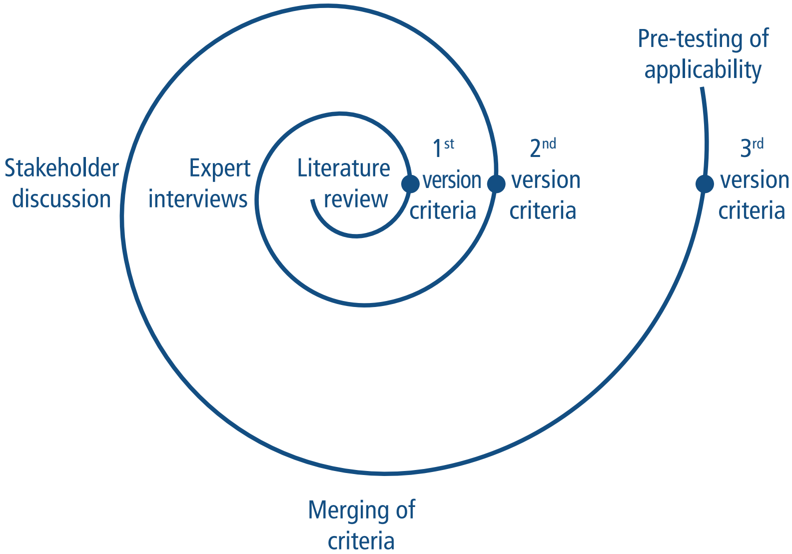

Fig. 6.1 Methodological approach to developing the evaluation framework

University of Natural Resources and Life Sciences, Vienna. Practical online evaluation guidelines were screened from citizen science organisations worldwide and websites that provide access to citizen science resources and projects (www.buergerschaffenwissen.de, scistarter.com, Citizen Science Central from the Cornell Lab of Ornithology, Centre for Ecology and Hydrology). Analysis of current evaluation practice focused mainly on areas in which citizen science projects differ from non-participatory scientific projects, such as communication, learning, technology participation and data management. The analysis was reinforced by 10 semi-structured expert interviews and expert consultation to gain feedback on scope, completeness, usefulness and applicability of the evaluation criteria and framework. The experts from Austria and Germany were selected based on their different approaches towards citizen science, covering practical as well as theoretical and evaluation-specific expertise, and with an even gender ratio. Further, a stakeholder workshop was conducted with 20 representatives of Austrian citizen science projects and four representatives of the funding body, the Austrian Federal Ministry of Science, Research and Economy to gain insight into the genesis of a citizen science project or programme.

Citizen science evaluation framework

Three core dimensions of evaluation emerged: 1) scientific dimension, 2) participant dimension and 3) socio-ecological and economic dimension (see table 6.1). For each of these dimensions, criteria are proposed at the 'process and feasibility' level as well as at the 'outcome and impact' level.

This framework can be applied for:

- Strategic planning and funding assessments of citizen science proposals;
- Monitoring progress during project duration; and
- Assessing impact at the end of a project.

In the course of the project lifecycle, the emphasis of evaluation would gradually shift from process and feasibility to outcome and impact. Process and feasibility ensures that projects prepare the groundwork for upcoming activities by engaging with concepts, methodologies and adaptive planning during their initial phase. Outcome and impact come into play when the first impacts on science, citizens and socio-ecological/economic systems can be measured.

Table 6.1 Citizen science evaluation framework

Dimension	Process and feasibility	Outcome and impact
Scientific	• Scientific objectives • Data and systems • Evaluation and adaptation • Collaboration and synergies	• Scientific knowledge and publications • New research fields and structures • New knowledge resources
Participant	• Target group alignment • Degree of involvement • Facilitation and communication	• Knowledge and science literacy • Behaviour and ownership • Motivation and engagement
Socio-ecological and economic	• Target group alignment • Active involvement • Collaboration and synergies	• Societal impact • Ecological impact • Wider innovation potential

Scientific dimension

Indicators at the *process and feasibility level* analyse the scientific grounding of the citizen science project. A clearly defined and genuine research question is the scientific basis of all future activities. It should be appropriate to citizen science approaches and meet the interests of participants (whether in terms of societal relevance or basic scientific curiosity). Good data quality control and validation processes are crucial success factors. Conceptual approaches such as research ethics, the proper management of (open) data as well as intellectual property rights issues need to be addressed from the beginning (see Williams et al. in this volume for more on these issues). Progress monitoring is also important; it should allow for flexibility and may lead to adaptive management during the project. New forms of sustainable collaboration between scientists, citizens and other societal actors and groups are also relevant here.

At the *outcome and impact level*, projects should be evaluated according to traditional academic standards, such as the generation of genuine scientific knowledge, captured in publications and possibly leading to new projects or collaborations. In addition, indicators should assess project impact on institutional or organisational structures and new forms of integrating traditional and local knowledge, thereby facilitating true knowledge exchange between science and society (see also Danielsen et al. in this volume).

Participant dimension

At the *process and feasibility level*, project design needs to include engagement and communication strategies. These should cater to different participant groups in terms of levels of engagement and interactive support measures and training to facilitate successful participation and collaboration (see Haklay in this volume). Working with civic society organisations may facilitate the participation of specific target groups and individuals with a genuine interest in the topic.

When it comes to assessing the *outcomes and potential impact* at the individual level, personal learning and development gains are key. Did participants develop new knowledge or skills, and does that increase their understanding of, and attitude towards, science? Did they enjoy the project and/or gain personal satisfaction from contributing to science and possibly to (local) policy development? Personal gains by individual participants may lead to changes in attitude and behaviour as well as an increased sense of ownership and empowerment, while the participation

Table 6.2 Evaluation criteria and supporting questions

Dimension	Criteria	Supporting questions
Scientific	***Process and feasibility***	
	Scientific objectives (Principles 1, 2, 3)*	
	Scientific goals	• Are the scientific goals sufficiently clear and authentic? • Is the scientific objective appropriate to citizen science? • Does the project adhere to the principle of joint knowledge creation in citizen science? • Does the scientific objective have relevance for society and does it address a socially relevant problem?
	Data and systems (Principles 2, 3,7,10)	
	Data quality and standards	• Does the project have clear processes defined to validate and guarantee high data quality? • Does the data adhere to common standards?
	Ethics, data protection, Intellectual Property Rights (IPR)	• Does the project have a data management plan, IPR strategy and ethical guidelines? • Are data ownership and access rights clear and transparent? • Is the data handling process transparent? • Do citizens know what the data is used for, and where it is stored and shared?
	Openness, interfaces	• Does the project have open interfaces to connect to other systems and platforms? • Is the generated data shared publicly and if so, under which conditions? • Is the project data appropriately archived for future analysis?

Table 6.2 (continued)

Dimension	Criteria	Supporting questions
Scientific	***Process and feasibility***	
	Evaluation and adaptation (Principle 9)	
	Project evaluation	• Does the project have a sound evaluation concept, considering scientific as well as societal outcomes? • Does the evaluation concept include indicators regarding the impact on individual participants and users of the project results? • Is evaluation planned at strategic points of the project?
	Adaptive project management	• Are project structures adaptive and reactive, including feedback loops for adaptation, and possibly a scoping phase? • Does the project have an appropriate risk management plan?
	Collaboration and synergies	
	Collaboration and synergies	• Does the project collaborate with other initiatives at the (inter-) national level to enhance mutual learning? • Does the project link to experts from other disciplines?
	Outcome and impact	
	Scientific impact (Principles 6, 8, 9)	
	Scientific knowledge and publications	• Does the project demonstrate an appropriate publication strategy, both in scientific and other media outlets? • Are citizen scientists recognised in publications and if so, can they participate in the dissemination of results?
	New fields of research and research structures	• Did the project generate new research questions, projects or proposals? • Did the project contribute to any institutional or structural changes?

(continued)

Table 6.2 (continued)

Dimension	Criteria	Supporting questions
Scientific	***Outcome and impact***	
	Scientific impact (Principles 6, 8, 9)	
	New knowledge resources	• Does the project ease access to traditional and local knowledge resources? • Does the project contribute to a better understanding of science in society?
Participant	***Process and feasibility***	
	Involvement and support (Principles 1, 4)	
	Target group alignment	• Does the project have an involvement plan that considers specifics of different target groups? • Are the options for participation and the degree of involvement diversified (e.g., gamification)?
	Degree of participation intensity	• Can citizens participate in various project phases? • Do citizens and scientists work as mutually respected partners in the knowledge generation process?
	Facilitation and communication	• Are support and training measures adapted to the different participant groups? • Are objectives and results clearly and transparently communicated? • Do citizens receive regular feedback? • How interactively is communication and collaboration between scientists and citizens organised?
	Outcome and impact	
	Individual development (Principle 3)	
	Knowledge, skills, competencies	• What are the learning outcomes with regards to new knowledge, skills and competencies for the participants?

Table 6.2 (continued)

Dimension	Criteria	Supporting questions
Participant	***Outcome and impact***	
	Individual development (Principle 3)	
	Science literacy	• Does the project contribute to a better understanding of science? • Does the project contribute to a better understanding of the scientific topic?
	Behaviour and ownership	• Does the project foster ownership amongst participants? • Does the project contribute to facilitating personal change in behaviour or political citizenship?
	Motivation and engagement	• Does the project raise motivation, self-esteem and empowerment amongst participants? • Are participants motivated to continue the project or involve in similar activities?
Socio-ecological and economic		
	Process and feasibility	
	Dissemination & communication (Principle 5)	
	Target group alignment & active involvement, two-way communication	• Does the project have a targeted outreach and communication strategy to reach a wide audience? • Does the project include innovative means of science communication and popular media, (e.g., art or hands-on experiences)? • Do citizens have the possibility for two-way communication?
	Collaboration and synergies	• Are collaborations planned with the media and science communication professionals? • Does the project leverage civic society organisations for communication and synergies?

(continued)

Table 6.2 (continued)

Dimension	Criteria	Supporting questions
Socio-ecological and economic		
	Outcome and impact	
	Societal impact (Principle 9)	
	Collective capacity	• Does the project contribute to the collective capacity of the participants in achieving common goals?
	Political participation	• Does the project stimulate political participation?
		• Does the project impact on policy processes and decision-making (e.g., through agenda-setting or data contribution for policy evaluation)?
	Ecological impact (Principle 10)	
	Targeted interventions, control function	• Does the project include objectives that protect and enhance natural resources and/or foster environmental protection?
		• Does the project contribute to higher awareness, knowledge and responsibility for the natural environment?
	Wider innovation potential (Principles 9, 10)	
	New technologies	• Does the project foster the use or development of new technologies?
	Sustainability, social innovation practice	• Does the project consider sustainability (environmental impact or sustained social relations) as part of the project plan?
		• Are the project results transferable to other contexts or organisations?
		• Does the project contribute to social, technical or political innovation?
	Economic potential, market opportunities	• Does the project generate any economic impact or competitive advantages, (e.g., cost reduction, new job creation, new business models, etc.)?
		• Does the project foster co-operation for exploitation, (e.g., with social entrepreneurs)?

* Principles mentioned in this table refer to ECSA principles (Robinson et al. in this volume)

of young citizens may raise their interest in embarking on a science career (see also Edwards et al.; Makuch & Aczel; Harlin et al., all in this volume).

Socio-ecological and economic dimension

Appropriate dissemination and outreach activities need to be considered at the *process and feasibility level* to enhance the wider social, ecological and economic impacts of citizen science projects. Key stakeholders need to be engaged in a two-way dialogue to foster ownership and participation. Seeking collaborations with, for example, civic society organisations, tend to further enhance visibility and impact.

At the *outcome and impact level*, the wider societal impact should be assessed in terms of increasing civic resilience, social cohesion and social impact. Depending on the project, a focus on environmental or economic impact might be appropriate (see Owen & Parker; Schroer et al., both in this volume). The wider innovation potential of citizen science should be addressed against its contribution to societal transformation and sustainability goals.

Overarching assessment criteria can also be matched with supporting questions to qualify and detail potential evidence for each criterion (table 6.2). Such questions offer guidance for planning, monitoring and assessing citizen science projects, and have a reflective purpose, meaning that they should be tailored to specific projects or programmes. A mix of qualitative and quantitative assessment methods is recommended to collect the necessary data to answer these questions, such as online surveys, usage statistics, interviews, focus groups and so forth. The evaluation instruments need to be embedded in a solid evaluation plan tailored to each project, which may include concrete benchmarking of measurable targets to assess success during and after the project.

Discussion of the evaluation framework and its applicability

The presented framework touches one of the most relevant aspects of citizen science – how to evaluate citizen science? The developed open framework allows project managers and funders, the main target groups of this framework, to expand and adapt the evaluation criteria according to their specific needs. Adding the participant dimension on an equal level to the scientific and socio-ecological and economic dimensions indicates an expansion of focus from more traditional scientific projects. Empowering citizens and facilitating critical participation is on equal terms with scientific objectives, triggering a need for new research designs (Sieber & Haklay 2015).

Key decisions about framework implementation should be informed by a project's target groups and processes. It is also important to identify whether project evaluation will be performed by project members themselves, funding agencies, external experts or as a collaborative effort. Importantly, evaluation should be included in time and resource budgeting. Gathering evidence is resource-intensive and projects should seek a balanced approach in terms of measures and expected outcomes.

If funding organisations plan to apply such a framework of evaluation criteria, the definitions of citizen science and expectations towards it need to be clearly communicated (Eitzel et al. 2017). Support measures, including specific evaluation guidelines and methods for proper evaluation, will need to be developed, and can build on existing guidance (e.g., Pocock et al. 2014b; Pettibone et al. 2016) and the evaluation criteria framework presented in this paper.

The framework is intended to be comprehensive and its application needs tailoring and contextualising according to the spatial, temporal and socio-economic demands of the project or programme. Criteria need to be prioritised and may receive different weighting depending on project goals. While all Ten Principles of Citizen Science hold for all initiatives (Robinson et al. in this volume), some projects might have a special focus on social goals and succeed in creating greater societal impact, although they might not open new research fields or have economic potential. Nevertheless, all three dimensions – scientific, participant, and socio-ecological and economic – should be considered to benefit from the full potential of science-society collaboration. Synergies and trade-offs will need to be considered, and an initial clear set of criteria and evaluative scales adds transparency to the whole process. Recording and monitoring project experiences along this criteria framework is required to evaluate and demonstrate good practice examples that may inform the development of successful citizen science.

Overall, while a framework should be clear, adaptive capacity and openness is needed to embed learning and development in the project lifecycle. While evaluation should be comprehensive, it should not be static. In the course of a citizen science project, which often runs for years, the framework should allow for reflection on developments and contextual changes. In addition, long-term monitoring is necessary to capture a project's far-reaching impact.

Conclusions

This chapter has presented a citizen science evaluation framework that integrates three assessment dimensions: scientific advancement, citizen engagement and socio-ecological/economic impact. The evaluation criteria matrix and supporting questions can – and should – be tailored to different purposes.

For funding agencies, the framework could inform the development and selection of evaluation criteria for citizen science initiatives. For citizen science projects, the supporting questions can support holistic reflection on project strengths and weaknesses, as well as the potential for improvement both during project planning but also for adaptive project management and impact assessment. For scientific organisations, the three equal dimensions might enrich reflections on citizen engagement and impact on socio-ecological/economic systems. For civic society organisations, a closer look at the scientific perspective might offer opportunities to better exploit benefits from collaboration with science.

Thus the evaluation framework can be used as (a) a planning instrument for designing projects; (b) a mid-term and final self-evaluation for projects; and c) an external evaluation for funding agencies.

The presented framework needs to be transformed into a practical assessment tool for projects and initiatives, preferably through a mix of qualitative and quantitative methods, such as tailored online surveys, usage statistics, in-depth interviews or focus groups. It can assist in strategic planning, monitoring and impact assessment. It is hoped that these evaluation criteria will trigger further discussion on measures of success and evaluation for different project approaches and contextual settings within the wider citizen science community. Overall, a proper evaluation framework will help to professionalise the citizen science community, foster and guide targeted funding support and, ultimately, increase the desired impact of citizen science on science and society.