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EVALUATING CITIZEN SCIENCE PROJECTS

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Purpose: For several years, the trend of open science and citizen science as one of its pillars has been developing rapidly in Poland. More and more research projects involving volunteer non-scientists are being carried out as part of citizen science. To know the scientific, educational and social value of these activities requires relying on the evaluation of these projects, which, however, is missing due to their novelty and difference from conventional science or commercial research. The purpose of this article is to propose evaluation criteria and methods that will meet the specifics and needs of citizen science projects.
Design/methodology/approach: The article is based on a critical analysis of the literature on the subject, as well as a systematic review of selected examples of completed citizen science projects - available on dedicated websites created by citizen science associations and other social and scientific organizations. Citizen science, as part of open science, is a relatively new and developing approach to scientific and educational activities. Evaluation research, on the other hand, is a method well-established in theory and put into practice for valuing results and enhancing the quality of projects, both of scientific and social character.
Findings: Citizen science projects require the implementation of evaluation models that take into account both the diversity of goals set for these projects, as well as the diversity and participatory nature of its stakeholders, and the study in terms of social impact. A higher level of involvement of volunteers in an ongoing citizen science project should presuppose the implementation of continuous evaluation and carried out in multiple areas of the project (organizational, scientific, social) to ensure the reliability and credibility of the results obtained, as well as to understand the mechanisms of their impact on volunteers and society.
Practical implications: The knowledge provided in the article can be used in planning and managing the evaluation of citizen science projects.
Social implications: Implementation of evaluation as a permanent practice in this type of projects can contribute to improving their quality, better management of public funds allocated to them, and greater public confidence in the knowledge produced within their framework.
Originality/value: The issue of evaluation in citizen science projects is relatively new, and appropriate evaluation models have not yet been developed. It is of interest to researchers and project managers, decision makers of public funds, scientists and the general public.

Keywords: project evaluation, citizen science, open science, democratization of science.

Category of the paper: Research paper.

1. Introduction

Citizen science is considered part of the open science movement, and at the same time represents an autonomous trend in which the public (non-scientists) is included in the implementation of scientific research. Thanks to information and communication technologies, it is developing in diverse forms of open access to databases and scientific publications, and facilitating collaboration among scientists around the world. The development of open science programs is supported by many international organizations, including the European Commission, UNESCO, as well as non-governmental associations and foundations. The open access policy has become a priority element of the EU's Framework Program for Supporting Research and Innovation 2014-2020. Within the framework of the HORIZON program as well, the 2020-24 strategy allocates special grant tracks for the implementation of projects in the areas of open science and citizen science[1].

Citizen science develops the ideas of open science (mainly in the form of free access to knowledge resources), but also goes further, pointing to the active role of society (through volunteer non-scientists) in the development and dissemination of science. It implements some of the values proclaimed within the democratization of science movement (McCormick, 2007) and prompts questions that are increasingly being asked about the science-society, science-decision-maker relationship described in the Third Wave of Science Studies (Collins, Evans, 2002). These include questions about the place of science in a pluralistic society; the monopoly and legitimacy of scientific knowledge and the status of non-academic knowledge; and the use of knowledge to legitimize public decisions (Wierzchosławski, 2021, p. 51). The values of truth and goodness that guide science are complemented in the citizen science stream by democracy, pluralism, justice and responsibility - values that underlie the concept of sustainable development (Kuzior, 2019). Citizen science can play an important role in monitoring the implementation of the Sustainable Development Goals, providing data for its evaluation from the perspective of diverse groups and communities.

Originally, the functions of citizen science referred primarily to assistance by volunteers (non-scientists) in data collection. The earliest projects were implemented mainly in the area of natural sciences (observations of specific animal and plant species, water quality studies, etc.) and astronomy (sky observations). However, over time, opportunities for a fuller and more collaborative involvement of the public in the creation of science were recognized, and more collaborative projects were undertaken, including those from more scientific fields - humanities, social sciences, health sciences and others.

[1] A description of the completed projects and a schedule of further competitions can be found on the European Commission's website: https://cordis.europa.eu/article/id/435872-citizen-science-inspiring-examples-of-societal-engagement-for-horizon-europe/pl (access: 12.08.2022).

With the development of citizen science, there were also criticisms, relating both to the certainty and reliability of the data collected and the knowledge obtained from it, as well as to the very idea of science practiced with the participation of citizen non-scientists. Among other things, it was stressed that not every type of research is equally suitable for implementation with the participation of volunteers. The lack of proper control over the data collection process and the lack of competence to interpret the data by volunteers were also pointed out. Organizational difficulties and uncertainty about the continuity of the research project, as well as difficulties in clearly defining the copyright of the results obtained from such projects, were also a matter of concern to the scientific community. The first studies of an evaluative nature compared the quality of data collected by volunteers with those collected by scientists (Gommerman, Monroe, 2012). Today, these can be described as the minimum scope of evaluation, far from being sufficient to fully understand and evaluate citizen science projects and their social outcomes.

2. Development of citizen science projects and the need for its evaluation

The dynamic development of citizen science projects can be followed, among other things, on dedicated online platforms. They allow their initiators to attract and contact volunteers, organize online research, and share databases, research results and articles. The most popular platforms include:

- zooniverse (https://www.zooniverse.org/) currently comprising more than 2,501,000 volunteers and 103 active and 79 completed projects in 11 scientific fields, which have resulted in more than 250 scientific publications;
- scistarter (https://scistarter.org) with 100,000 active volunteers and more than 3,000 projects (of which 1,600 are active);
- citizenlab (https://www.citizenlab.co) with 2,500,000 projects, over 750,000 volunteers;
- ECSA - European Citizen Science Association (https://eu-citizen.science) with 189 active and 29 completed projects from 12 European countries. It provides nearly 190 scientific publications in its resources;
- RRI Tools (https://rri-tools.eu) with more than 1,640 projects and 2,400 volunteers, active in over 30 countries.

With the exponential growth of citizen science projects, new levels of volunteer involvement in research activities have also emerged, as described by Muki Haklay (2013), among others, referring to S.R. Arnstein's typology of public participation (Arnstein, 1969):

Level 1 - Crowdsourcing - volunteers are involved in obtaining basic data, checking indicators, reading simple data.

Level 2 - Distributed Intelligence - it is up to volunteers to collect data and create databases, sometimes also simple analysis and interpretation of the results obtained. Projects provide training for participants and prepare materials to help them properly perform research, code, read or interpret results.

Level 3 - Participatory science - at this level, volunteers are involved in defining research problems, determining the research process, and collecting and analyzing data. This level is also often educational research, focused on volunteers' learning about the research methodology and process.

Level 4 - Extreme Citizen Science - creating science in partnership between scientists and volunteers. This partnership encompasses the entire project from defining the problem, determining the methodology, collecting data, analyzing it and drawing conclusions. It's also participation in the dissemination of results for use in social and political decisions (Halaky, 2013).

Despite the rapid development of citizen science projects, their impact on society may be more of a promise than a real fact. It is limited by various social and cultural factors, such as:

- Direct and institutional trust (between scientists and non-scientists) about the reliability and certainty of the knowledge produced by these projects. Citizen science projects, despite the wealth of data provided, are not taken as seriously in the scientific community as conventional science. Many prestigious journals only recognize the educational value of articles based on these data (Bonney et al., 2014).
- The willingness of non-scientists (volunteers) to commit to knowledge creation - their level of motivation to participate in citizen science programs, their willingness to learn continuously - lifelong learning, their honesty and integrity in applying certain methodological procedures.
- The confidence of decision-makers in the knowledge produced by citizen science and their willingness to use and implement its results in public decisions.
- The openness of society to new knowledge and understanding of science (the concept of PUS - Public Understanding of Science), the readiness of people to implement changes in their lives on the basis of new scientific knowledge created in citizen science projects (Bonney et al., 2015).

A natural turn in the development of citizen science is the increasingly significant inclusion of evaluation, as an answer to questions about the meaning of citizen science projects, as well as the quality of the data provided and the knowledge created through the work of volunteers. Evaluation of citizen science projects can reach out to many important issues, such as the social relevance of citizen science, the benefits/risks of participation in these projects (in terms of awareness and knowledge of the surrounding world, trust in science, knowledge of the scientific process and methodology, etc.), democratization of science, making science results public, strengthening innovation and public involvement of citizens. It is also an opportunity to further improve citizen science projects and disseminate and implement the results of scientific research in society.

3. Functions of evaluation - between impact evaluation, supporting development and building public confidence in citizen science

The largest number of citizen science projects, and at the same time evaluation studies, relate to projects carried out at levels I and II of citizen science and in the field of life sciences. Both the experience of researchers working with volunteers and the evaluation studies carried out show that the collection of quantitative data by volunteers, produces relatively good results, satisfying professionals and giving volunteers a sense of true participation in the creation of science. The importance of good preparation of information materials and training for volunteers - on which the quality of the data obtained depended to a large extent - was recognized. If these materials were properly prepared the quality of data collected by volunteers was comparable to professional scientific research. In contrast, citizen science projects focused on qualitative research are more difficult to implement and often do not produce adequate and reliable data for professionals. These studies also require more sophisticated evaluation methods to improve the quality of the research process itself and to identify the causes of problems and opportunities to achieve better research results also in the collection and analysis of qualitative data (Gommerman, Monroe, 2012).

Evaluation prepared for the development of a project should take into account all stages of the project from the study of needs and the start of implementation, through the monitoring of the process to the study of impact. For most citizen science projects, it is worthwhile to start it even before the project (ex-ante evaluation), conduct a needs analysis not only of the participants - volunteers, but also of other groups involved in the project (scientists, community, project recipients and others). Part of the questions should make it possible to compare some indicators with an adequate survey conducted also after the end of the project (ex-post evaluation). For example, the participants' awareness and knowledge of the research problems undertaken, awareness of the methodology of the research process, attitudes towards the topics addressed and behaviors associated with them, motivation to participate in the project, expectations of the project and its results. The dependence of the types of evaluation and its scope on the stage of project implementation is shown in Figure 1.

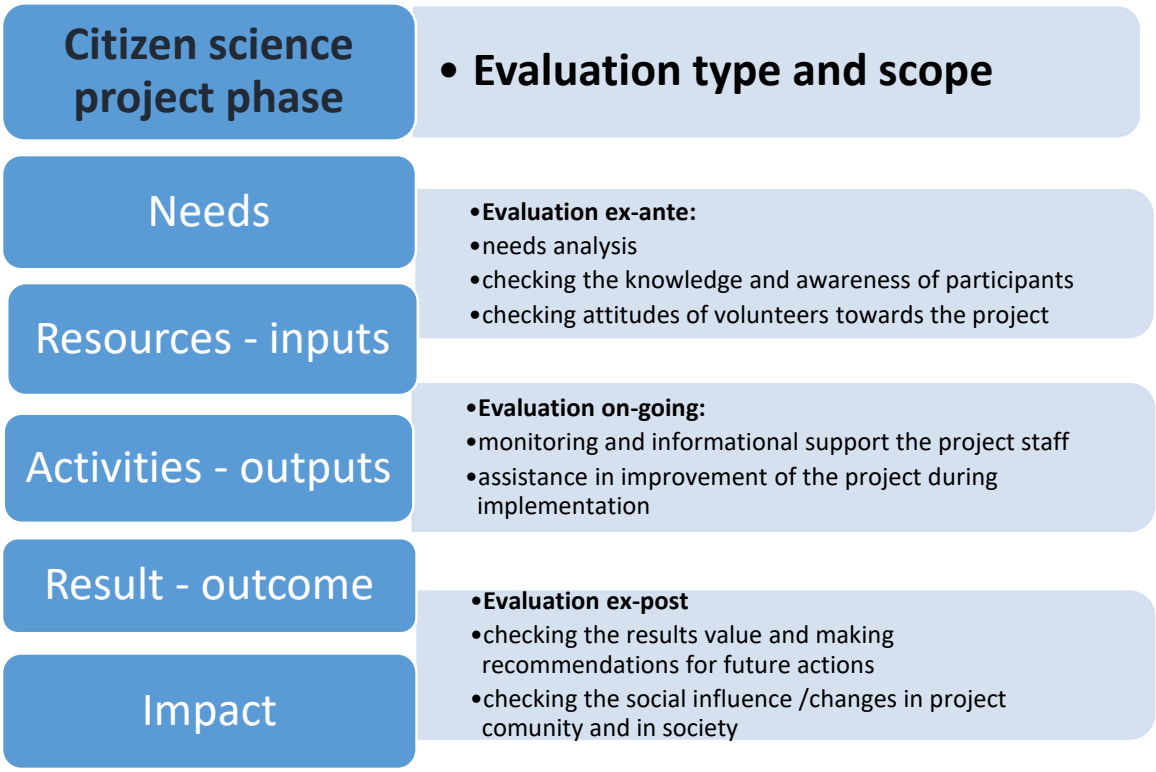

Figure 1. Dependence of types and scope of evaluation on the stage of citizen science project implementation.

Source: own study.

The authors of many publications emphasize that the evaluation of citizen science projects should be carried out, at least in three areas, because of the goals that these projects can achieve:

- in terms of scientific result,
- in terms of learning and strengthening the participation of participants (volunteers),
- in terms of social impact (Kieslinger et al., 2018).

Evaluation in terms of scientific result is usually based on the study of the quantity and quality of data collected by volunteers and the number of scientific publications and their citations published based on the data collected in the project. The first is most often carried out by project managers themselves - as a kind of self-evaluation to develop the project and/or legitimize its results. The second is carried out by external evaluators, examining the scientific process in the project, often also as a meta-evaluation - comparing the scientific impact of publications relying on different citizen science projects. Their results can be found on citizen science platforms. For example, the eBird platform (https://ebird.org/home) aggregates more than 5 million bird observations, which it makes publicly available so that they can be analyzed. It also offers access to several hundred scientific articles developed on the basis of the observations compiled within its framework. The credibility of citizen science projects is also built by subjecting its projects (databases, analyses and results) to peer-reviews on the same basis as conventional science data and analyses.

The achievement of scientific goals, with which citizen science projects are most commonly associated, will not always be positively correlated with educational goals and in terms of impact on social behavior. The evaluations of many projects have shown an increase in awareness and knowledge of the subject undertaken by the citizen science project. For example, in the increase in knowledge of invasive plant species, but the desired change in the behavior of volunteers towards invasive species has not already been achieved. The authors of this exemplary evaluation looked for reasons for this situation in several factors, primarily related to the organization of the research process: too little time after training volunteers for their personal reflection and insufficient opportunities to learn from practice and from mistakes. Important factors that can influence the achievement of the desired behavioral change among volunteers include strengthening their sense of agency and control over the phenomenon, and raising the level of motivation and personal commitment to the research topic undertaken (Bonney et al., 2015). To achieve this, volunteers must not be treated as a cog in the machine, unaware of the whole of its operation. They must understand and want to learn about the phenomenon under study (cognitive curiosity), as well as know how their individual action will translate into the final scientific result (sense of agency). Therefore, studying the motivation of volunteers can be crucial to project development.

In some citizen science projects, the learning evaluation included not only the problems (knowledge and practice) of a particular project, but also a general understanding of the research process and awareness of the scientific method. One such example is the MicroMundo@Valencia project on antibiotic resistance carried out by an international research team at the University of Valencia in 2017-19. As part of the project's evaluation, a survey was conducted with the elementary and secondary school students and university students involved. In addition to questions about knowledge of antibiotic resistance, the survey included a block of questions on interest in science, understanding of science, and volunteers' assessment of the relevance of scientific research (Maicas et al., 2020). This evaluation approach makes it possible to answer the question - to what extent do citizen science projects contribute to a better understanding of science and its principles in general? It also provides a basis for examining the level of public trust in science, which is a necessary component of citizen participation in the development of scientific knowledge and its integration into everyday social life.

Social impact is not only the most difficult goal of citizen science projects to study, but also the least present element in evaluation studies of these projects. They usually remain at the level of studying the knowledge and educational or participatory values of the projects. Even if behavioral change is shown as part of the evaluation, it refers only to volunteers, and its most common expression is talking to close people (family, friends) about the project's issues (Jordan et al., 2011). Meanwhile, the transfer of knowledge requires not only its transmission, but also the use of language that is understandable to the audience, as well as two-way, active communication about aspects of these projects that are of interest to both parties (Sobieraj, 2019). The idea is not just to adapt reports to the linguistic capabilities of the audience, but

rather to involve volunteers of citizen science projects in communicating to the public about their goals, course and achieved results in categories attractive to them. Projects with a higher level of volunteer involvement are characterized by a more practical approach to the problems studied (Jordan eat al., 2012).

4. Evaluation tailored to the needs of citizen science projects

Attempts to create evaluation models and select indicators for different levels of citizen science have already been made in practice and presented in the literature, but both the abundance of approaches to citizen science projects and the need for "tailor-made" evaluations make these only a certain theoretical and methodological framework within which evaluations of citizen science programs can be designed. Such a proposal can be found, among others, in the publication: *Evaluating citizen science, toward an open framework*, whose authors, based on an analysis of the literature and evaluation reports from citizen science projects, proposed their own set of guidelines and criteria for evaluating citizen science programs, divided into three areas of impact: scientific, participatory and socioeconomic. The most important criteria listed there include:

1. **scientific dimension:** process and feasibility of the project, data quality and compliance with standards, data protection and copyright preservation, clarity of access rights, archiving and making data public, scientific collaboration, publication strategy, generation of new research questions and areas.
2. **participatory dimension:** target group of the project, levels of participation in the project, support of volunteers in participation and involvement, feedback to volunteers, quality of volunteer participation and openness to new groups, scope and level of knowledge, skills and competencies acquired by participants, level of motivation of volunteers, their attitudes towards the project topics and their understanding of scientific procedures, satisfaction with participation in the project.
3. **socio-economic dimension:** effectiveness of communication strategies with the social environment, level of cooperation with the media, two-way communication and participation in social discourse, focus on achieving common goals for the community, level of public interest, impact on the social and ecological environment, participation in sustainable development, development of networks with institutions of the social environment (Kieslinger et al., 2018).

In proposing a framework for evaluation, however, it is inevitable to take into account the diversity of approaches to citizen science projects, as one of the factors determining the goals, methods and organization of projects, as well as the intended results. R. Bonney et al. distinguished four types of citizen science projects based on the nature of volunteers' participation in them and the goals they pursue:

- Data collection by volunteers.
- Data processing by volunteers - coding, transcription, categorization, interpretation.
- Projects based on educational programs, often national or even global in nature, carried out in schools, community organizations or other informal settings bringing together youth or interest groups.
- Community-based learning projects, most often those grounded in a local area, aimed at solving specific practical problems of that community using scientific knowledge (Bonney et al., 2015).

Based on these four types of civic projects, four different evaluation models can be proposed, corresponding to the assumptions and characteristics of these projects (Fig. 2). The evaluation models listed are based on Ernest R. House's typology of approaches (House, 1997) and complemented by participatory evaluation, which is widespread today.

System evaluation is mainly oriented to quantitative analysis, based on the study of pre-accepted performance indicators, allowing comparability of data. Its intended primary audience is project managers.

Expert model is based on the evaluation of the quality of the results produced by the project in relation to the standards accepted in science. The method used in it is an expert opinion, a scientific review whose recipients are professionals - the scientific community and the public.

Democratic evaluation is a model based on understanding diversity and taking it into account in the evaluation of project goals and results. The use of qualitative methods, interviews, case studies and others allows to gather and understand the opinions of different groups of stakeholders of the project being evaluated.

Participatory model, on the other hand, is based on dialogue and active cooperation with those being evaluated from the beginning of the project. Its best form is action research, through which the evaluation simultaneously leads to the development of the project and its results are used directly during its course.

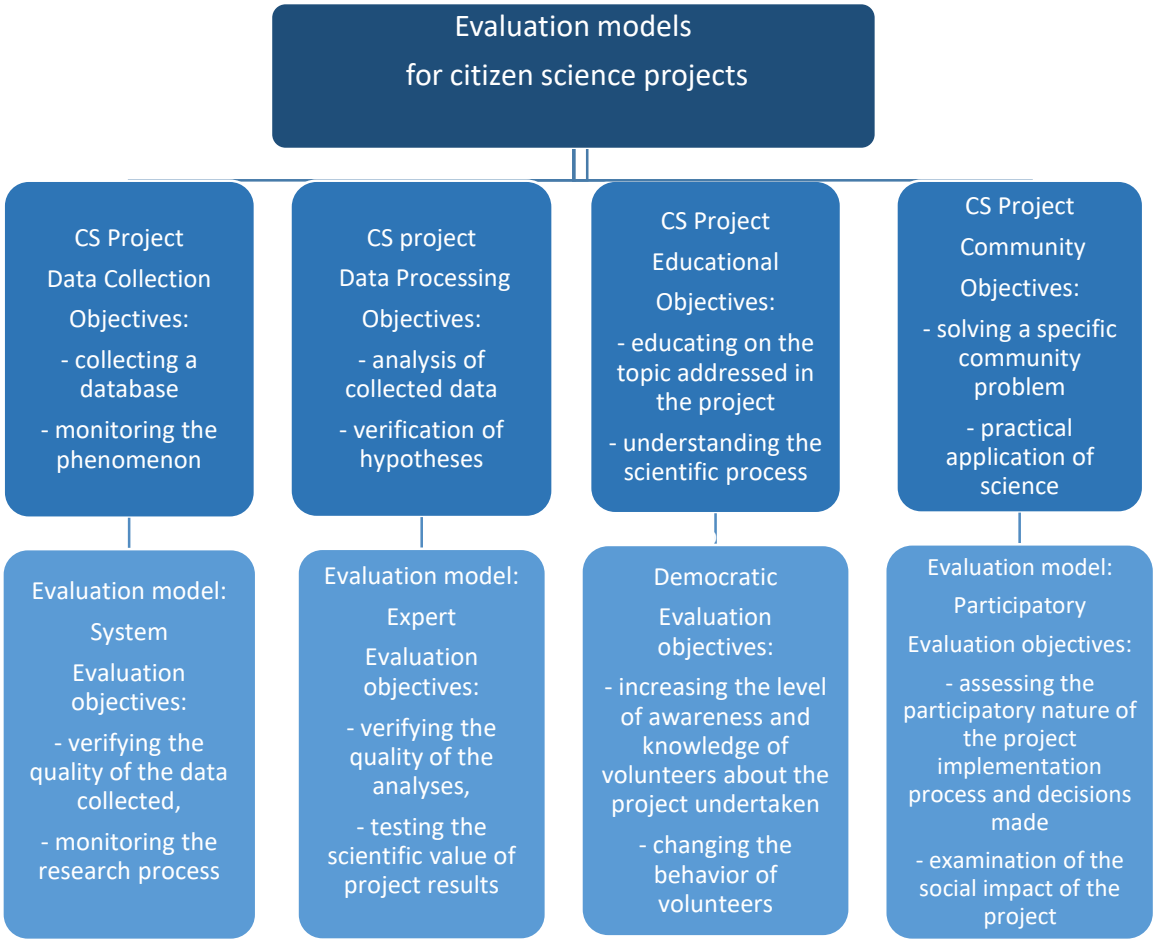

Figure 2. Dependence of the evaluation model on the type of citizen science project.

Source: types of citizen science projects based on (Bonney et al., 2015), typology of corresponding evaluation models - own study based on (House).

A challenge for evaluation, but also for the management of citizen science projects, lies in their increasing number around the world, coupled with a simultaneous lack of proper coordination. This results in duplication of similar data, often incomparable, produced in similar locations. That causes confusion for volunteers, but also limits the reach and impact of competing projects. The solution is to develop global cooperation and enter into partnerships with existing programs, by expanding their bases and the subject matter undertaken. The benefit is not only the development of existing projects, but also the ability to build on proven methodological solutions, tools and training for volunteers, as well as the relevance of the bases created. Evaluation of citizen science projects should also examine the goals and results of cooperation at this highest level of cooperation, in relation not so much to individual projects, but to entire platforms and methods of managing individual projects, as well as their impact on the development of these programs. This dimension of evaluation is not yet being addressed.

5. Conclusion

The systematic development of evaluation in the area of citizen science can contribute to breaking down the barriers between conventional science and citizen science, and at the same time to strengthening the process of democratization of science. It requires scientists to be open to participating in new projects and knowledge exchange networks, and to be willing to go beyond the usual patterns of research procedures. On the other hand, it requires citizen science managers to accept external evaluation of the scientific quality of the process and results of their research on the same terms to which conventional science is subject.

Nonetheless, the success of citizen science projects should be determined by the evaluation process, with reference to all the goals it sets out to achieve. Focusing solely on scientific results, gives us only partial knowledge of the results and impact of citizen science project implementation in society. A strong and successful scientific process in these projects will, of course, strengthen the chances of obtaining reliable and credible research data, but is not the only benefit that comes from the implementation of these projects. These very goals are addressed by citizen science projects, which rely on higher levels of participant involvement and partnership throughout the scientific process. The task of evaluation is to show their effects and results in a full scale.

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