ISSN 2385-2755
DiSSE Working papers
[online]

SAPIENZA
UNIVERSITÀ DI ROMA

WORKING PAPERS SERIES
DIPARTIMENTO DI SCIENZE SOCIALI ED ECONOMICHE

The practice of Citizen Science and the process of energy transition. A possible field of application.

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N. 14/2024

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CF80209930587 – P.IVA 02133771002

The practice of Citizen Science and the process of energy transition. A possible field of application.

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Abstract

The term Citizen Science (CS) refers to the involvement of citizen volunteers in carrying out scientific research projects. Such processes have existed for a very long time and have mostly been employed in research in the natural, biological, and technical sciences. The role of the volunteer has always been, especially in the past, to collect data to be processed in collaboration with the responsible experts. Citizen Science is seen as a tool for democratising science and opening up knowledge, albeit with some criticism. In recent years, Citizen Science has also been opening up to the humanities and social sciences. These are sometimes used as a theoretical framework to frame issues of public participation or contextualisation of practice and are less frequently referred to as actual Citizen Social Sciences projects, although recent funding actions by political institutions (in Europe, there are examples of Horizon 2020 first and Horizon Europe later) have encouraged their implementation. The UN Agenda 2030 and the need for systemic ecological, environmental and energy transitions have raised the question of the role of civil society within processes of almost revolutionary scope. In this case, social sciences could use the tools provided by CS practice to research the impacts of energy transition and formulate policy proposals or political support together with citizens.

Introduction

The proposed paper aims to reconstruct the scientific debate built around the practice of citizen science, starting with definitions (of which there are many) and then going on to study fields of application and experiences, finally focusing on the environmental and energy fields. The reconstruction of this debate aims to understand whether, specifically in the field of social sciences, Citizen Science can be a useful tool to address issues and opportunities related to the energy

transition since it is no longer possible to overlook the key role of citizen users at the centre of this change in this specific sociotechnical system.

The reconstruction of the scientific debate took place through the systematic literature review by comparing the search results on the 'Web of Science' and 'Scopus', using various queries related to citizen science, all in English. Furthermore, the downloadable data were processed using Bibliometrix and Biblioshiny, a library of the open access software 'R', and thanks to this collection, it was possible to identify the most frequently cited articles and authors, the topics most frequently discussed in the papers, and also the most frequent words associated with a specific query.

Citizen Science is a set of more or less informal heterogeneous practices (Giardullo et al., 2022) involving citizens in the scientific research process. Many scholars highlight the contradictions of Citizen Science: on the one hand, it is an educational tool for engagement, personal empowerment and democratisation of science thanks to participatory practice (Crucitti, 2016); it allows the increase of knowledge and scientific production useful to bridge the gap between society and the scientific community (Sauermann et al., 2020) sometimes remedying the distrust citizens feel towards scientists (Kasperowski & Kullenberg, 2019). It can, however, also be delineated as a neo-liberal tool useful for the ever-increasing need to produce scientific products, thanks to the voluntary involvement of citizens (Vohland et al., 2021).

Today, the debate focuses heavily on issues related to the evaluation and quality of the work offered by citizen volunteers (Vohland et al., 2021 & Giardullo et al., 2022). The fields of application of Citizen Science practices have mostly been related to the collection of data, observations and measurements in the field of natural sciences, originating in fact in the field of ornithology (Irwin, 1995 & Strasser et al., 2019). Currently, the focus on Citizen Science has grown, and the knowledge towards which 'shared science' is moving is also other and especially related to environmental sustainability and policy development. Involvement practices have been institutionalised, for example, by the European Union, through the instrument of Horizon 2020, then Horizon Europe 2021-2027, and by the ECSA (European Citizen Science Association), so that, together with citizens, shared policies can be constructed based on evidence that the

volunteers themselves have been able to collect: alongside research classically linked to natural sciences, there are projects focusing on climate justice and pollution, for example.

Decisions on ecological issues also refer to the energy transition, which today is one of the most debated topics on international political agendas. When it comes to energy, the implementation of Citizen Science has mainly been linked to the analysis of energy consumption, whereas today, a greater need seems to have arisen to include citizens in the stakeholder debate (Nijkamp et al., 2023) who are able to weigh in on the decisions to be made in view of this sociotechnical change.

The first part of the article reconstructs the debate concerning the definitions and traditional application of Citizen Science, then the field of natural and technical sciences; the second paragraph emphasises the centrality of both formal and informal educational issues in CS processes. The third paragraph, on the other hand, reconstructs the political centrality, especially in funding, that the practice has been experiencing in recent years. The fourth and fifth are more focused on the role of social sciences in Citizen Science and the possibility of their use in issues related to the energy transition.

1. Citizen Science: multiple definitions and fields of application

It could be said that Citizen Science has a long history: Caren Cooper (2016) tells how as early as 1835 when the term Citizen Science did not exist, some citizens working at tide stations became involved in a study by scientist William Whewell and how they were asked to observe and record high and low tide for two months.

The birth of these practices is closely linked to the natural sciences, first and foremost. Ornithology, meteorology, the observation of flora and fauna, astronomy, and disciplines related to biology are the scientific fields from which CS comes to life.

Two centuries ago, when the first experiences of total citizen involvement in the scientific process took place, there was neither name nor definition for a practice

that, over time, has emerged, in some disciplines, as central and of great utility in advancing research on a large scale.

The term Citizen Science still encompasses a vast number of definitions, linked to different disciplines, but also to different visions of the same practice and its usefulness and effectiveness. Generalising as much as possible, all definitions include among their main points the involvement of citizens who become part of the scientific research process alongside professional researchers and scientists.

Since the second half of this century, attention to this practice (or rather practices) has increased and so has the desire to give it a definition and describe its activities. Vohland et al. (2021) propose a list of 34 definitions from encyclopaedias, associations, institutions and academia: these differ from one another, but have several points in common. First of all, some of these offer more emphasis on the voluntariness of the citizen taking part in such projects, others focus on cooperation and collaboration. Still others highlight the more widespread activities that citizen volunteers are called upon to carry out, and finally, there are (a few) definitions that emphasise the political dimension of these projects and the importance in the construction of political-scientific governance.

The OECD in 2022, in the "OECD Guidelines for Citizen Participation Process", placing CS within the general framework of participatory practices, emphasises its importance in fostering democracy and inclusion, implementing good policies and developing useful projects, but at the same time frames the process as needing citizen volunteers with particular skills, while on the other hand, many argue that the strength of this practice is that it can involve citizens who are simply curious or passionate about a particular scientific field, without necessarily having any prior skills or knowledge - although this aspect might call into question the quality of the data collected.

The European Citizen Science Association proposes the ten principles of Citizen Science, and although the document states that "*Citizen science is a flexible concept which can be adapted and applied within different situations and disciplines*" (ECSA, 2015, pg.1) what is proposed is a rich and inclusive list of most of the aspects that are dealt with by the most disparate definitions: from the importance of education

to the original project outcome, to the quality of the data collected and analysed, but also the aspects related to the recognition and intellectual property of volunteers.

We could identify, as Barboza-Gomez et al. (2022) write, three types of this same

practice: contributive, collaborative and co-creative, differentiated according to the degree of citizen/volunteer involvement.

Citizen Science, therefore, is presented according to different filters, which, on the one hand, can justify the theory that CS processes can be useful to democratise scientific processes (increasingly politicised in a more scientificised politics), but also that it is the appropriate tool to consolidate a trust relationship between science and civil society (Kasperowski & Kullenberg, 2019).

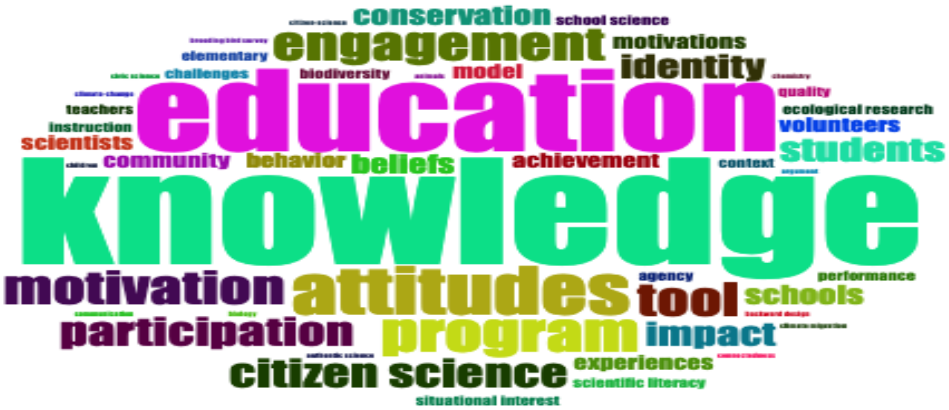
Supporting not only scientists but also politics can be the task of a citizen joining such projects (Strasser et al., 2018), aspiring to a possible democratisation not only of the scientific process but also of the political one.

Thanks to 'Bibliometrix' (software package 'R'), it was possible to process some results from the Web of Science search of the query 'citizen science', limited to the social sciences. A total of 155 articles were selected.

Figure 1. WordCloud processed via Biblioshiny

There are many keywords in the social sciences, on which we can also reflect in order to better understand the multitude of concepts that go hand in hand with

Citizen Science and which also help us to understand why a multitude of definitions exist.



Democracy, participation and support at first sight are the keys that are most striking in reference to this practice, but it is also useful to dwell on other concepts that are recurrent within the literature when we speak of citizens becoming part of scientific research, such as education and engagement.

2. Education, engagement: the basis of Citizen Science

Figure 2.WordCloud processed via Biblioshiny

What also emerges from the study of literature and definitions is the importance given to the concepts of engagement and education.

Regarding the last concept, in fact, some authors, such as Phillips and others (2012), echoing Friedman (2008), state that CS can fully fall under the concept of informal scientific learning.

Citizen Science is, on the one hand, a suitable tool for increasing the scientific literacy of ordinary citizens, but it is also a suitable tool for increasing the knowledge of students of the disciplines involved, through university projects of joint research with expert scientists (Mitchell et al, 2017); thus the educational objective of these practices can be carried out both in formal settings and modalities (where the concept of volunteer can be questioned), and in informal settings and modalities.

Formal environments, especially schools and universities, provide for collaboration not only with students but also with the educators responsible for the educational institution, doubling the learning process by extending it to these latter figures, who may often lack the necessary scientific literacy. The impact of embedding CS (understood as students' full participation in scientific research) within formal learning processes could be twofold: on the one hand, it stimulates the individual curiosity of individual students, enabling them to investigate aspects they find interesting; on the other hand, it helps students to become more aware and interested citizens of society's problems (Lüsse et al, 2022); the implementation of this type of practice, however, must somehow align scientific and educational goals, although the time teachers can devote to CS is limited, experiences show the great potential on pupils engaged in collaborative projects with teachers and scientists (*ibid.*, 2022).

Roche et al. (2020) define informal environments as all those outside the classrooms of educational institutions; therefore, museums and science centres are also categorised as such. It is in these contexts that Citizen Science projects are activated, involving more volunteers who, out of interest, ideology and personal ethics, decide to engage in a path of subjective education, but also one of collective utility, as well as a path of experiential education (Crall et al., 2010), capable of triggering a change in the attitudes and behaviour of 'scientists to be'. The concepts of 'engagement' and, consequently, that of 'active citizenship' fit perfectly into the construction universe of Citizen Science.

Volunteers who choose to take part in these experiences are recognised in many studies as knowledgeable, attentive, sensitive and motivated to the concerns of society and nature, but also curious, interested and enthusiastic about science.

Phillips et al. (2019) writing about engagement in CS point out that several quantitative studies have been done over the years to measure it. The research by Phillips et al. in question, however, is unique of its kind to date and proposes a good classification of citizen engagement in Citizen Science projects and the motivations that drive them: a sphere related to the activities to be carried out, a series of positive feelings such as enthusiasm, the possibility of learning new knowledge and the social dimension (the relational aspect with other volunteers and scientists, for example).

The literature has often been interested in the effects that participation in CS projects has on citizen volunteers, who can perform a work of translation, i.e. they can transport the good practices and approaches they have learned to everyday life (McNew-Birren & Gaul-Stout, 2022). There are several studies demonstrating the effectiveness of participation in Citizen Science projects, although volunteers must have the ability to make themselves partly autonomous from experts in order to be able to judge their impact fruitfully by recognising its scientific value (Lewenstein, 2022).

3. Citizen Science: politics, science and unequal opportunities

A participatory instrument is, first and foremost, a political instrument. Citizen Science, although a *sui generis* participatory practice, is equally so.

The proof of this statement can be seen in the funding possibilities that the European Union has provided for projects of this kind since Horizon 2020. Confirmed then with the Horizon Europe funding programme (2021-2027). Indeed, the intention of these research programmes is to open up science more and more to citizens, and CS is the optimal and already tried and tested instrument for this.

To date, there are research strands that are more predisposed to the use of this practice than others, and these are mostly those related to ecological transition and environmental sustainability. Obviously, CS has always been employed in the fields of natural sciences, and for this reason, its connection with the defence of nature and the environment remains alive and well - moreover, it is in these

fields that, over the years, a greater capacity for using scientist/citizen co-design methodologies has been structured.

Citizen Science can be a means of democratising science, of entering and familiarising oneself with something that would otherwise be relegated to an elite, in this case, experts. On the one hand, it is clear that opening the doors of scientific research to civil society is, in theory, a positive element and seems only likely to bring an improvement to science and the relationship between it and non-specialist society. On the other hand, however, it is necessary to explore the criticalities that are embedded in the ever-increasing affirmation of participatory practices, including Citizen Science.

The employment of a large number of non-professional scientists in the field of research may invoke the idea of a voluntary de-emphasisation and externalisation of the tasks of the state and politics, which might choose to use the data and proposals from major CS projects to study policy and interventions (Schade et al., 2021); responding, therefore, to the real demands of the citizens who have collected and studied those data, but also highlighting the neoliberal trends of cutting research funding (Lave et al., 2010), which, somehow forced, has to rely on volunteers to progress with knowledge and consider them as a free labour force at the service of scientific progress (Strasser et al., 2018).

When we speak of volunteers, however, we are referring to the possibility of anyone being involved in these practices, and this is how it should be. Citizen Science, however, is not - of course - an ideal-typical model, and for this very reason, it reflects social issues. Science and, consequently CS are not fair; they respond to the needs and demands of a part of society and most likely involve only a part of it, the so-called desirable groups: those who are already educated and have a high cultural and scientific capital (Soleri et al., 2016; Giardullo, 2023; Archer et al., 2015). Sometimes, the presentation of Citizen Science projects proposes the sweetened view that participation is the remedy for inequality and discrimination, but this is not always the case: not everyone has equal access to science and the information it produces. Lewenstein (2022) argues that in several of the projects he analysed, the access of women and ethnic minorities was significantly lower than the participation of white men, for example, partly

because they were more directly involved in the issues the research set out to investigate (*ibid.*).

A further element to focus on (when speaking of participatory practices in general and specifically at CS) is the communication and technologies deployed for the dissemination and implementation of projects.

Just as science literacy is crucial in accessing Citizen Science practice, so too is digital literacy. The so-called digital divide resulting, for example, from the intertwining of social, economic and educational variables (Tirocchi, 2015) is another barrier to entry into CS projects. As will be seen later, one of the easiest and quickest ways to carry out participatory projects of this kind today is the creation of web-based platforms that allow for a larger number of adhesions to be collected, enabling international exchange of ideas and results within a short timeframe. The massive use of social networks as a means of contact between volunteers and researchers is also a feature of CS today.

While the use of online platforms of various kinds represents a facilitation, a speeding up and an internationalisation of projects, these modalities also underline how CS can be considered a practice exclusively for those with certain types of knowledge, skills and tools.

4. **Citizen Social Science: between natural and social sciences**

It is often pointed out in the literature that the social sciences (but also the humanities) have always lagged behind in terms of involvement in initiatives related to scientific research, its promotion and the relationship of science with citizens and society at large (Campos et al., 2021). Reaffirming that CS is configured as a tool to bring 'ordinary' citizens closer to science, the contribution of the social sciences, in this sense, can be important: hence the possibility of declining the same practice in ways that are related and useful to the social sciences themselves, creating a new strand, namely that of Citizen Social Science (CSS).

The establishment of Citizen Science in Europe could be said to have taken place in 2014 when the European Citizen Science Association (ECSA) was formed.

On the presentation page of its website, ECSA defines the line on which it decides to move: '*Our main goals are to increase the democratisation of science, encourage the growth of citizen science in Europe, and support the participation of the general public in research processes – across the natural sciences, social sciences, humanities, and the arts*'. The association, based in the Museum für Naturkunde in Berlin, has a large number of researchers and academics among its founding members and on the board. It currently has around 20 ongoing projects in which it is a partner and which have been implemented thanks to the allocated European funds. With a view to analysing the state of the art, which is a prerequisite for this work, it is interesting how a large association such as ECSA wants to propose projects that are able to go beyond the topics that have always been dear to those involved in Citizen Science: in addition to the natural and technical sciences, there are in fact many projects related to the social sciences and socio-economic transitions towards sustainability. The main objective of the European Citizen Science Association, as they themselves declared, is to respond to the demands and needs related to the Sustainable Development Goals (SDGs).

The 'AGORA' project, for example, provides insight into how addressing certain climate change challenges requires perspectives that can go beyond the natural sciences. Although the latter is necessary to study and find solutions to environmental and ecological problems, the social sciences are an excellent ally in creating tools for collaboration and social acceptance of innovations and good practices.

Another project worth mentioning is 'COESO' (https://coeso.hypotheses.org/): entirely dedicated to the desire to promote and disseminate the use of Citizen Science in the humanities and social sciences by (in turn) deploying smaller pilot projects that enable social science literacy. A major innovation introduced by 'COESO' is undoubtedly the 'VERA' platform (https://coeso.hypotheses.org/6356). Through the latter, in fact, aspiring volunteers can find projects of interest to them, consult them, but also have the opportunity to get in touch with those already involved in Citizen Science actions in order to create dialogue, relations and horizontal knowledge. Furthermore, through the platform, it is possible to enter one's own project and find volunteer collaborators to carry it forward.

In addition to ECSA, of which only two examples of the intersection between natural and social sciences have been mentioned, the experience of Professor Jennifer Gabrys, lecturer in the Department of Sociology at the University of Cambridge, is also of great interest. Thanks to a grant from the European Union, she has been able to carry out several 'Citizen Sense' projects (https://www.jennifergabrys.net/projects/), in which the citizens involved are actually engaged in issues concerning the environment and air quality in an urban environment. The elements that Gabrys brings to his work reflect the strong multidisciplinary nature that Citizen Science has been adopting in recent years. Indeed, citizen volunteers focus on research that intersects technological innovation, environmental concerns and citizenship.

The openness of Citizen Science towards the humanities and social sciences is not an isolated fact. In recent decades, there has been a shift towards understanding science in society (Heiss & Matthes, 2017) and, thus, there has been a need to open up to a multitude of actors not necessarily familiar with the natural and technical sciences but also a need to create a collaboration with another type of science downgraded for years (Tauginienė, 2020), which could also lead to a new, specific type of CS, namely Citizen Social Sciences (Henke, 2022).

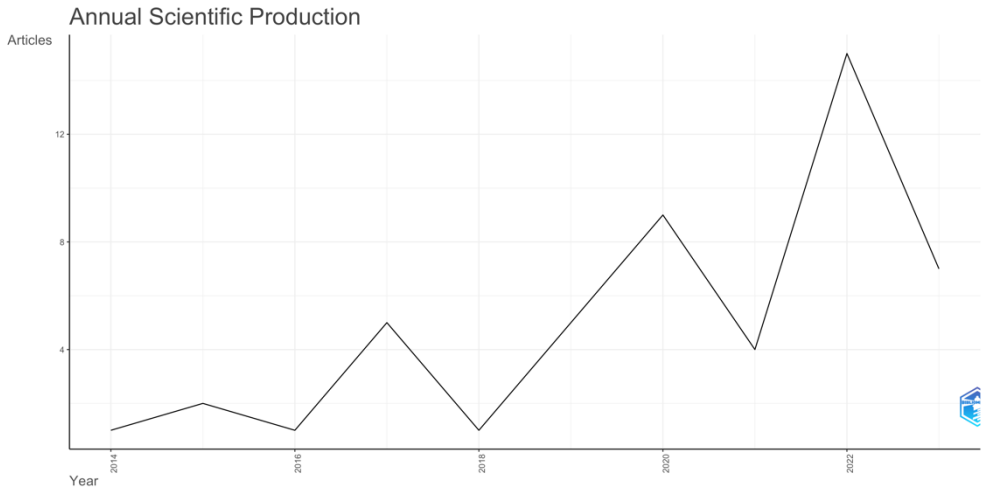


Figure 3. Graph of annual scientific production on Citizen Sciences and Social Sciences, processed with biblioshiny on Web Of Science data

The academic world, through scientific production (as can be seen in Figure 3), began to take a greater interest in Citizen Science in the social sciences from

2014 onwards, with an increasing interest over the years, culminating in a peak in 2022, which will presumably continue in the current year. However, social sciences are often included within other types of projects as a theoretical underpinning, to highlight the benefit of participation and collaboration or to focus attention on new fields or perspectives within a CS project of another discipline, always remaining somewhat obscured (ibid.), but it is interesting evidence that more and more is being talked about and studied over the years.

5. Citizen Science perspectives for the study of energy transition

As widely anticipated in this article, achieving the goals of the United Nations' Sustainable Development Agenda is one of the current vehicles for implementing Citizen Science experiences.

Among the identified Goals, the seventh and eleventh are of particular interest to this research: the first aims to ensure that everyone has access to affordable, sustainable, clean and modern energy systems. An important step to achieve this goal is the facilitation of international cooperation to access research and technologies useful for clean energy production. The thirteenth goal to be achieved in the 2030 Agenda is the fight against climate change, for which it is necessary to decrease CO_2 emissions, thus also changing the energy system linked to fossil resources.

What the achievement of these important goals envisages is a major change in the sociotechnical system within which society moves and in which change it must take part, co-constructing it and evolving hand in hand (Elzen et al., 2004; Savaget et al., 2019). Citizen involvement emerges as a viable avenue to make this multilevel system change more functional (Hyysalo, 2021) and frame CS and CSS projects as 'intermediary functions' (Blasutig, 2017) in bringing about policy cycles and social acceptance.

Citizen Social Sciences can be effective in building bottom-up processes capable of creating new knowledge, but also in building a solid base of social acceptance of systemic changes, with faster and more concrete effects (Henke, 2022). CSS can, therefore, be understood as a useful governance tool; the use of

methodologies and issues dear to the social sciences can be a vehicle for the promotion, adoption and acceptance of policies of different kinds (Kythreotis et al., 2019) with a focus on those related to environmental instances.

Citizens, who cease to be merely 'users', can thus play a dual role as researchers, but also as policy decision support, especially when it comes to co-creative CS projects - those in which the involvement of the volunteer is greater and he or she participates from start to finish in the research project, from the formulation of questions and hypotheses to the dissemination of data and results.

Barbosa et al., in 2022, propose the results of a branch of the EU-funded 'GRECO' project on solar energy. Citizens involved in the research project from the beginning collected and worked on data related to solar panels installed on their properties, contributing to the improvement of the technological performance of these artefacts.

When it comes to wind energy and plants built to harness this valuable renewable resource, Citizen Science can also be considered a good tool.

Further studies have highlighted the possibility of citizenship intervention in CO2 Capture and Storage research, although in this case the contribution of volunteers was mainly focused on the evaluation and analysis of potential costs and benefits in relation to the possibility of installing such plants on a given territory (Terwel & Ter Mors, 2015).

In general, the process of energy efficiency and the reduction of CO2 emissions certainly has a strong impact on society and therefore, more Citizen Science projects are expected to be developed, although at present only a small percentage (in 2020, 3%) of the projects hinged on Goal 7 of the SDGs envisage the implementation of such projects. (De Filippo et al., 2020).

Energy innovation, however, changes the plane of governance, inevitably shifting it towards new stakeholders, i.e. citizens: energy is essential in the human activities of the urbanised world, and it is unthinkable to change the rules of the game by keeping players out of the process. Citizen Social Sciences may be able to bring citizens into the planning arena on energy transition (Nijkamp et al., 2023). Moreover, as Scotti (2020) points out, putting projects of this nature in the field when it comes to energy transition (with particular reference to the exploitation of renewable resources) in even more informal contexts can be a

good tool to study and put on the table instances in environments where there is not the pressure typical of institutional places where the logic of the market and economic efficiency could alter the citizen's cognitive and decision-making process; thus returning to the concept of democracy and free access to public decision-making.

Conclusions and future research perspectives

In conclusion, what emerges from this review of the literature on Citizen Science is a picture of a well-established practice that over the years has conquered an ever-increasing share of research experiences. Participating in it means donating scientific, sometimes academic, knowledge on the part of researchers and everyday life experience on the part of volunteer citizens, creating a two-way sharing of sometimes different aspects and worlds. It is certainly true, however, that in order to participate in these projects it is necessary to be familiar with the world of research in some way, even if only for passion's sake, and it is also important that the topics interest the volunteer and this, as we have already seen, is not always inclusive.

The natural and technical sciences have the temporal advantage of having explored the potential of this participatory approach to science some time ago, so much so that Citizen Science courses are now being created in the departments of these scientific fields at universities (at the University of Padua, for example, it will begin in this academic year). The social sciences, on the other hand, are only more recently approaching this type of participatory practice and are not yet able to detach themselves completely from the natural sciences, as they often remain an instrument of the latter, or the involvement of social scientists within CS projects is a useful figure for facilitating processes and communication between researchers and volunteer researchers.

Today, when we talk about the transition to sustainability, the social sciences and the physical, natural and technical sciences must necessarily dialogue with each other: change in the sociotechnical system requires collaboration at different

levels; technological change has a strong social impact, probably more than in the past.

Social research, which follows the same principles and rules as the physical and natural sciences, can field entirely innovative Citizen Science projects that are able to make an important contribution to systemic change in the transition, especially the energy transition. Planning and evaluation, which political and social sciences in general have always practised, can, for instance, be extended to citizen volunteers. Typical social research tools can also be repurposed and brought into Citizen Science, such as the drafting, administration and analysis of questionnaire results on specific issues.

In the future, it may be interesting to continue to follow the developments of the recently established Italian Citizen Science Association and also try to monitor how social scientists are involved in the process. Following up and monitoring involves empirical research, which has recently begun, by means of semi-structured interviews with some of the actors of the steering committee and also volunteers.

Furthermore, since Citizen Science research is related to research on the public acceptance of energy transition technologies, in the not-too-distant future it will be useful to be able to carry out comparative studies between social science projects on the subject of energy transition technologies, whether or not they use Citizen Science, in order to obtain empirical results on its impact on social acceptance. Citizen Science can act as a counterbalance to the exclusively top-down dissemination processes that are deployed at the introduction of major changes, but it will be interesting to observe how the two different - and opposite - modalities also manage inevitable situations of conflict and difficult management of civil society's reactions to an avoidable and massive change.

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