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Citizen Science: which kind of public participation is epistemologically feasible?

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Abstract

Projects concerning the participation of citizens to the scientific research have become very popular in recent years. However, the literature seems not offer much foundational investigations into the epistemological conditions that make citizens' contribution to science a fruitful and rigorous activity. Research institutions and citizens, understood as entities bearing generally distinct requests, practices and goals, knowledge and skills, are totally misaligned. In order to participate to collaborative research, citizens need an epistemic and methodological literacy to overcome common sense ideas, towards an ever adequate vision of phenomena under investigation. Besides understanding the social advantages introduced by the participatory dimension, it is therefore necessary to analyze the related epistemological problems, to understand to what extent and in what respect to the participation of citizens to research processes might be regarded as truly advantageous from an epistemological perspective.

Keywords: Citizen science; Participatory Science; Co-creation; Common sense.[3]

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1. Introduction

In recent years, we are witnessing the spreading of more and more projects that include participatory processes within scientific research activities. While, according to many practitioners in several areas of science, this process seems new, it has instead a long history (Miller-Rushing et al., 2012) and has given the possibility to tackle research questions that otherwise would have been too difficult to address without the involvement of large numbers of data collectors. The most recent diffusion of participatory methodologies spread out stimulated by at least two different objectives. On the one hand, it is motivated by the idea that bringing scientific research to deal with concrete problems of the world, and so bending the research to citizen-informed applicative purposes might be bearer of great social benefits. On the other, it is meant as a strategy to raise awareness and educate the lay public about the importance, results and usefulness of scientific knowledge. Therefore, participatory approaches can be expedient for improving the scientific literacy and for encouraging dissemination through involvement (Bonney et al., 2009a). Moreover, the collection of data usually hidden to researchers or distributed through non-easily accessible channels can make this collaborative partnership helpful for building new scientific insights, and so providing researchers with a deeper understanding of phenomena under investigation.

It seems pretty obvious that these participatory processes lead to a shift in the relationship between science and society, as they represent an attempt to stem defects arising from the so called “deficit model”, i.e. a unidirectional approach from science towards society, in terms of scientific applications, knowledge transfer, scientific awareness and science communication. Examples of this approach are the standard technology transfer model, in which the research is first carried out in academies and then made available to interested parties, or the scientific communication from the so-called “ivory tower” to the lay public (Ziman, 1968; Baron, 2010).

Nowadays, participatory processes can take various forms and can be based on different organizational methodologies. They can be focused on the participation of heterogeneous citizens, as well as of citizens (or other stakeholders) who meet some entry criteria. Undoubtedly, the Citizen Science (CS hereinafter) is the most well-known and widespread approach. It has the merit of opening the doors to the large diffusion of such participatory dimension in science. Since the first appearance of this idea, and of the term itself, which seems to have occurred in 1989 (Hacklay et al., 2021) to codify the use of scientific activities by citizen volunteers, the forms of scientific participation have taken various paths, in such a way that today a clear definition about how these processes are structured and organized is difficult to establish. Initially, the concept was rooted in a basic involvement of non-professionals in scientific research. Indeed, the term was used to indicate an approach in which a politically or socially relevant issue was addressed, and citizens from some specific geographical area were invited to collect or generate data useful to provide possible solutions (Kerson, 1989). This approach was used to emphasize the participation of people by contributing with data or labor to professional scientific endeavors, often in fields like ornithology or astronomy. Today, CS’ projects encompass a wide array of activities, from crowdsourced data collection through smartphone apps to community-led research initiatives addressing local environmental concerns. The proliferation of digital technologies and the democratization of scientific tools have led to a broadening of CS' boundaries, making it a multifaceted phenomenon that defies easy categorization.

CS' projects often include not only a participatory approach aimed at contributing to scientific knowledge but also an effective method for addressing a broad array of societal challenges. These projects encourage an open approach to science, supporting the goal of an inclusive society, enhancing communities, promoting public engagement, and reducing the distance between science and society. This broad spectrum of consequences is evident from the definitions selected by Mordechai et al. (2021), where a clear and concise specification of what CS projects include or should cover is missing. These definitions range from descriptive to normative elements, encompassing a diverse range of academic fields, each with its own objectives, worldviews, and approaches to knowledge. This ambiguity prevents a rigorous delimitation and evaluation of the features of CS projects.

CS is generally claimed to enhance scientific, technological, and engineering research, while also better connecting research evidence to decision-making and social innovation. From this perspective, and given the idea that science should be more attuned to societal needs, it is considered essential to maintain methodological flexibility and conciliate epistemic perspectives. But is this really possible? Indeed, as its conceptualization and approaches are not very clear or, in some cases, even contradictory (Wiggins and Wilbanks, 2019), such a methodological flexibility can easily lead to distorted uses and to short-sighted plannings (Ankeny and Barrie, 2019).

Building on this initial consideration, this contribution addresses the challenge of investigating the epistemological issues inherent in participatory projects. If science represents our best form of knowledge, how might the intention to shift its research direction toward local knowledge, basic common sense, and specific applications impact the research process itself? If this shift necessitates including citizens, who are often totally unaware of scientific knowledge and methodology, as active participants, can we exclude the risk of diluting the inherent value the reliability of science is based on? Furthermore, are we certain that the goal of active public participation, beyond being promoted in projects and socio-scientific literature, is genuinely implemented and followed as extensively as often described? The aim of this work is shedding some light on the epistemological aspects of CS in order to evaluate to what extent such projects may contribute to an effective construction of scientific knowledge.

Indeed, it is legitimate to consider and promote Citizen Science for its pedagogical, social, and political dimensions. However, the aim of this paper is to analyze and understand to what extent CS is really able to cope with epistemological challenges that the "co-creation" of scientific knowledge contributes to set. According to the ECSA, Citizen Science "*is an emerging area of research and practice, with evolving standards on which different stakeholders are developing methodologies, theories, and techniques.*"

This understanding aligns with ECSA's own expectations, as it seems "*useful to establish some level of shared understanding, across disciplines and practices, as to what to expect from an activity or a project*" (ECSA, 2015).

The participation invoked in scientific research seems to represent a regulatory ideal of current scientific design, prompted by political demands of useful outcomes for society. However, the central point, in our view, aligns with what Cooke and Kotari (2001), Shirk et al. (2012), and Woolley et al. (2016) assert: we must move beyond this "tyranny" or "populist rhetoric" of participation, which alone is insufficient to ensure appreciable results. Our goal is starting an investigation about identifying the crucial epistemological features, the advantages of participatory research design, and the methodological prescriptions to be adopted.

2. Common sense and scientific literacy

The concept of "common sense" frequently comes up in the field of epistemology and is a term that many philosophers use or mention. Nevertheless, despite its widespread use, defining common sense precisely and pinpointing specific items of knowledge as its products is challenging. Therefore, the term tends to be avoided in contexts that demand more precise language. The core notion identifies our usual understanding of practical issues or a sort of natural instinct where our perception and cognition give us a specific representation of the world. Related concepts include intuitions, pre-theoretical beliefs, everyday language, the frame problem, foundational beliefs, doxa, and similar ideas. In fact, common sense encompasses our understanding of everyday situations and how an average person perceives the world, providing practical solutions to daily issues. As we grow up, we all develop common sense, which helps us to act properly in society. Essentially, we can view common sense as consisting of the knowledge we take for granted. In academic discussions, it is believed that the difference between a layperson and a scientist is that, while the former relies solely on common sense, the latter pursues also scientific knowledge. A scientist does not confine herself to accept things as they are but seeks for a deeper understanding of *why* things are as they are.

Indeed, as one may argue, science, or scientific knowledge, refers to a specific type of knowledge that involves the study and understanding of the physical and natural world through careful reflection, observation, experimentation, and a systematic method of drawing conclusions. While common sense pertains to our everyday understanding, science extends further by offering scientific explanations for the realities we encounter in life and often take for granted. Some scholars have highlighted the distance between common sense and scientific knowledge (Nagel, 1961; Hoyningen-Huene, 2013) upon noticing that, although there are elements originating in common sense that are somehow involved in the scientific process, the latter should be neatly distinguished from the former.

Nagel claims that, first, common sense usually doesn't recognize its own limitations, such as the reliance on specific conditions for its validity, making one rarely aware of the limits within which such beliefs are successful, while science seeks to address these gaps.

Second, common sense often holds conflicting beliefs, and it is through the resolution of these conflicts that scientific progress is driven. Third, science reduces the ambiguity of everyday language by using a more precise vocabulary, allowing for more rigorous tests of its statements through experience, observation, and experimentation. Lastly, while common sense' knowledge is often tied to human values, scientific explanations disregard this aspect intentionally, or at least aspire to be as disengaged as possible from such values as possible.

There are areas of research in which a citizen having common sense as its sole background culture generally knows nothing (e.g., black holes, the atomic-molecular structure of matter, cognitive biases, advanced statistical measures in medicine) and is often unaware of the extent of her ignorance. Understanding such areas requires basic scientific education and expertise, features that people working in scientific institutions typically build through years of training. A similar situation occurs also in fields like agriculture and, broadly speaking, food production. For example, the usefulness of manure as a soil fertilizer is basic and widely known among all workers in the field and is used successfully all the time. However, only a few of them understand why this is the case and can provide a systematic explanation thereof. This results in a blind use of such knowledge, without considering consequences such as possible soil deterioration (Hoyningen-Huene, 2013), leading to difficulties in solving problems induced by possible impacts on food production. Similarly, the medicinal properties of some herbs have been recognized for centuries, but there is usually no explanation for their therapeutic virtues, no knowledge of the conditions under which they continue to function, or whether they may produce undesirable effects in certain cases. As Nagel states (1961, p. 4), "*when 'common sense' does attempt to give explanations for its facts [...] the explanations are frequently without critical tests of their relevance to the facts*".

Of course, scientific knowledge arises from common sense knowledge, as the former draws from the latter basic conceptions of objects, phenomena, and their perceived properties. This initial intuitive epistemic access leads also to the definition of an initial related language that seeks to identify key concepts with greater specificity, aiming to eliminate intuitive conceptual vagueness or indeterminacy, and clarify the relationships between them. Typical popular examples include formulations that require a "sufficient" amount to achieve something (or "just enough") or causal formulations that exclude other competing factors. This elimination is essential for obtaining more precise and reliable knowledge, with increasingly systematic explanations of the phenomena under investigation. This process leads to meeting more rigorous standards, making more precise and refutable predictions, and so to respond more effectively to the criteria of control and demarcation (Popper, 1959).

As Grieffenhagen and Sherman (2008) observe, the linguistic construction operated by science does not replace everyday language with scientific language, because everyday language persists in some contexts of daily life by preserving common-sense notions (e.g., the sun continues to rise in the east and move, even though scientific reality is known to be different). This makes plausible the idea that, in researchers, conceptual schemata generated by common sense are joined by other schemata, thus allowing for more refined tools and perspectives useful for understanding reality, and enabling reasoning within theoretical spaces inaccessible to laypeople. This helps to explain why, in order to allow them to profitably participate to research with researchers on a par, simple literacy that evolves from common sense knowledge is not enough. It is often necessary to acquire the ability to look at phenomena from a different theoretical perspective, which may even contradict basic intuitive beliefs. Actually, in some cases, the average citizen background may not struggle with what is needed to carry out research. (e.g., think to the collection of data concerning birds simple behavior) Therefore, concerning some subjects, the difference between laypeople and researchers becomes blurred (Ellis and Waterton, 2004). However, in more advanced knowledge, differences in thinking and skills remain significant.

In addition, common sense is rarely accompanied by a fallibilist attitude or sophisticated control strategies. According to Hoyningen-Huene (2013), science borrows from common sense the notions of objectivity and truth, which are straightforward from a superficial perspective: a statement is "objective" when it represents a phenomenon as it is, without any distortion by the reporting subject; a statement is "true" if it is adequate to the state of affairs it refers to. These ground notions form the basis of the "naive realism" that might occur in some scientific practices. However, from an epistemological perspective, this view is quite limited, because scientific knowledge is fallible, falsifiable, and continually subjected to evaluation (e.g., control samples or blind control). There is no way to establish the definitive "truth" behind an investigated phenomenon.

Moreover, as it pursues systematic knowledge, science differs greatly from common sense to the extent that it develops features that cannot be understood as a linear evolution of conceptual abstractions from initial cognitive practices. When areas of knowledge reach a high degree of maturity, they are characterized by reliable knowledge that is no longer related to common sense. While this advanced knowledge may not contradict common sense, it cannot be categorized as simple improvements with a greater number of details. Typically, from the first accepted theoretical hypotheses, new consequences can be deduced, new empirical tools can be constructed, and new phenomena can be observed that were previously beyond the scope of sensory and "intellectual" perception. Furthermore, new theoretical entities not previously considered by common sense can be contemplated. This process continues even in successful developments and is a distinctive feature of modern science, based on a cycle of knowledge production that is hypothesized and tested in various ways.

Furthermore, scientific research often produces knowledge that is partly at odds with common sense. We do not need to think only of emblematic and historically significant cases of scientific revolutions (Kuhn, 1962), such as the emergence of heliocentric theory, the affirmation of quantum theory, or the evolutionary theory of life linking us to primordial unicellular beings, which are totally impossible to understand from a common sense' perspective. Many ideas have been revolutionary with respect to common sense. For example, it took centuries to move beyond the idea that certain properties (like color and smell) were inherent in objects. Other revolutionary ideas include Einstein's concept of relative simultaneity and the understanding of the vast array of microscopic life forms that live in, on, and around us.

These ideas, which later became scientific knowledge, create a clear discontinuity with common sense and appear in almost every area of mature scientific knowledge. This discontinuity is one reason laypersons often struggle to understand scientific knowledge, as it is not accessible from their basic framework.

It should also be kept in mind that the time spent on research training serves many purposes: acquiring knowledge of the relevant scientific theories in a particular domain, understanding the conceptual assumptions in those theories, mastering research methodology and competence in its application, improving inferential abilities specific to the domain, understanding and mastering the justificatory strategies of science, which allow one to evaluate claims aspiring to scientific validity, and reducing cognitive biases that lead to interpretations and formulations with no scientific value.

In our opinion, participatory projects in scientific research, which proclaim themselves to enhance the co-creation of scientific knowledge, do not take sufficient account of the difficulty for the citizen's common sense to reach the level of abstraction scientific knowledge held by researchers is endowed with. And this is an essential part of the machinery needed to participate to the research. If citizens are not required to acquire the scientific mindset that researchers gain with he acquisition of relevant scientific theories and research methodologies, and if the only corrective measure proposed is to educate citizens on the main aspects of scientific practice, it is unclear how citizens can epistemically play the role of true co-creators.

Although the complexity of participative enterprises tends to challenge traditional notions of scientific authority and expertise, suggesting that the lines between amateurs and scientists are blurring, finding a solution allowing the scientific inquiry to become effectively more inclusive and flexible while maintaining the same rigor is still quite problematic.

3. Epistemological challenges and reliability

The challenge posed by participatory activities in science, starting with CS, strikes the philosophical core of science itself and challenges its usual recognized features on many levels. We identify an *epistemological* challenge, as participatory activities are aimed at the creation of new knowledge; a *methodological* challenge, as it is necessary to define which activities can be carried out correctly by the participants; and a challenge concerning *social practices*, since participation can occur in different ways and with various responsibilities in the participatory process itself (Hacklay et al., 2021).

The epistemological challenge focuses on the construction of scientific knowledge, which constitutes the best, most reliable, and most trustworthy kind of available knowledge. Its reliability is ensured by specific scientific communities, inspired by organized skepticism, which evaluate scientific claims critically before their acceptance or rejection. This evaluation conforms to "current" methodologies designed by means of discipline-specific peculiarities and protocols, as well as a code of disinterested conduct (Merton, 1973). They constitute the best tools available to generate reliable knowledge. Even if one embraces an anarchic idea of the scientific method, à la Feyerabend (2010), claims still need to "work" and make reliable predictions about the problems addressed, although beyond any methodological standardization. Following Popper (1985), one should always keep in mind the centrality of the justificatory process in the scientific reliability assessment. The context of discovery, i.e., the initial stage at which a theoretical hypothesis is conceived or imagined, is irrelevant to a logical analysis of scientific knowledge as it can arise in entirely unexpected ways, through creative intuition possibly involving irrational elements (Popper, 1959). In this case, the fact that hypotheses are foreshadowed by researcher or by citizens is not dispositive for providing them with a scientific status. The status of science relies on the next stage, the one of justification. This implies that to construct scientific knowledge, one must have a basic understanding of how that process of construction takes place and skills in applying that method (Boon and Van Baalen, 2019).

Therefore, regardless of the chosen participatory design, maintaining scientific rigor should be still considered a regulative ideal of research, even when shared with "external" actors. This is highlighted by the Ten Principles of Citizen Science (ECSA 2015), which emphasizes the need for valid scientific outcomes with correct methodology and research questions. Limitations and biases, as well as legal and ethical considerations, must be kept under control, starting from attribution and intellectual property issues to data sharing, confidentiality agreements, and security concerns.

In traditional science, the control of scientific quality—defining which problems can be investigated, how they are addressed, and what results are considered acceptable—primarily occurs within a community and institutionalized space, including universities, academies, and scientific societies. In participatory processes, however, the contexts of application and evaluation, although they include researchers trained in institutional spaces, are temporary and transitory, with more fluid and provisional boundaries. Control shifts from the disciplinary community to social contexts that include citizens and stakeholders, incorporating additional criteria such as efficiency or specific utility in that particular context (Gibbons et al., 1994).

As participatory models evolve, there is increasing pressure on researchers to implement broader models of engagement and collaboration (Wiggins et al., 2019), making these participatory contexts increasingly distant from the formal epistemic systems of science. This shift may result in relegating some crucial systemic elements aimed at ensuring the scientific justification and trustworthiness, think e.g. to peer review processes, to the background or, even worse, in their complete abandonment. This can lead to the acceptance of results that lack the scientific community peer review, the main guarantor of epistemic reliability, and the risk of amplifying problematic and misleading claims, unjustified results, and superficial theories.

4. Research challenges in participatory models

Participatory research activities can result from various designs with different purposes, not only in the context of the scientific inquiry they address but also in the model of public participation they employ. This heterogeneity of approaches, along with the confusion of terminology that has arisen with various projects, has not facilitated the understanding and effective use of their underlying ideas. The term "participatory research" has been linked primarily to large-scale data collection initiatives (Bonney et al., 2009b) as well as to the philosophy of engaging knowledge and skills of the lay public (Irwin, 1995).

The quality and quantity of participation are crucial factors to be considered when analyzing how participatory processes can enter and influence scientific research. The candidate parameters can be many, including the number and heterogeneity of participants, the duration of participation, and the quality and depth of engagement. Studies often depend on the degree and quality of participation. However, other relevant aspects are not usually considered, such as the research context, who leads the project (Wiggins et al., 2011), the main objective of the research activity (Riesch et al., 2014), and more subjective factors crucial in research training, such as credibility, trust, and diligence in developing research strategies. High-quality participation in research also requires alignment between the objectives of the research project and the interests and needs of the participating citizens. These factors are neither necessary nor sufficient to guarantee participation, but the literature shows they are closely correlated with the success of the participatory research project (Shirk et al., 2012). The different degrees of participation form the basis of the models identified by Bonney et al. (2009a) and Shirk et al. (2012). Shirk et al. contemplate models at the extreme ends of the scale, including cases where participation foresees citizens as “commissioners” of specific research projects to be conducted solely by researchers, and where citizens become completely independent researchers. However, the most interesting models for our analysis are those considered by both studies: *contributory projects*, *collaborative projects*, and *co-created projects*. These models always emphasize the pedagogical dimension towards citizenship at various levels.

Contributory projects are typically designed and led solely by researchers, with citizen volunteers primarily providing data useful for research. Examples include ecological projects where citizens observe and monitor natural phenomena such as butterflies or birds, invasive weeds, and environmental data (Strasser et al., 2019; Bonney et al., 2009a). The methodology behind sampling and data acquisition is crucial in these types of projects, representing one of the main challenges in CS projects and a highly debated issue due to its importance in ensuring a reliable evidence base. The ethical dimension regarding data collection is also relevant, particularly the truthful provision of data and the limitations of the methodology used. This aspect is especially critical when the research addresses a need of the participating citizens, who may be improperly pressured to distort the data collected in pursuit of their own interests.

More epistemically advanced activities are not typically involved in these types of projects. However, in Bonney and Shirk's models, it is expected that there may be minimal interaction even in data analysis, which is a central point of projects with higher levels of participation, such as collaborative and co-created projects. The popularity of CS projects is due largely to these contributory projects. Despite claims that participatory models are increasingly being developed with many contributions from nonprofessional citizens, Wiggins and Wilbanks (2019) and Bonney et al. (2009b) acknowledge that these contributions rely merely on data collection useful for research.

Collaborative projects are typically designed and led by researchers but foresee a deeper citizens' participation which goes beyond sampling and collecting data. This involvement primarily includes the analysis of the provided data. Other dimensions may also be involved, such as participation in designing the data collection methodology or even disseminating research outputs. Projects where citizen volunteers monitor environmental data (typically on water or air quality) may fall into this model. More specific examples include sharing medical or health-related data (Bonney et al., 2009a), where even minimal analysis of qualitative data is required. Researchers are still in charge, but the citizen's role is expanded to include more activities and responsibilities.

For these types of projects, it is important to understand how citizens can carry out sample and data analysis. Generally, citizens are capable only of intuitive data analysis, using minimal statistical tools. Considering the average citizen, we should expect limited knowledge of basic statistical tools. However, intuitive analysis is not what is typically expected of a professional researcher, who is trained to use more refined analysis tools and to avoid personal biases that are scientifically established limits of human reasoning (Kahneman, 2011). Moreover, it becomes relevant to our analysis that the scientific dimension is not granted by the discovery stage, which can occur in a variety of ways. What truly matters, and what provides reliability and the status of scientific knowledge, is the justification stage (Popper, 1959). Therefore, how can analysis be conducted in a way that adequately supports the interpretations made from the data? Typically, citizens are not literate enough to work on this in the manner that science requires.

Co-created projects involve much broader participation, distributed throughout all stages of the research, starting from its conception. In addition to the activities involved in collaborative projects, citizens in this model propose a problem to be solved and often work elbow to elbow with researchers. Several scholars have emphasized the community or socio-political aspect of this approach, as e.g. Cornwall and Jewkes (1995), who refer to it as "community science" or as "participatory action research." Typically, these projects involve citizens who have experiential knowledge about the problem being investigated and act to emancipate themselves from that problem. Examples include projects that aim to solve a pollution or social problem in a specific area, where the primary goal is community or organizational change (Cornish et al., 2023), or projects related to public health, where the participation of the people in the study is beneficial (Baum et al., 2006; Lenette, 2022). In these projects, knowledge generation is shared between researchers and citizens, and popular forms of knowledge are included. The initial stage of defining and choosing the research question can already be participatory, involving people with direct experience of the problem. However, defining the research question requires an understanding of tools and scientific knowledge available in the field.

Additional aspects generally required for developing co-created projects include developing plausible explanations and interpreting data to establish possible conclusions (Bonney et al., 2009a). Conducting these steps necessitates thorough scientific knowledge and inferential methodological competence within the discipline, allowing for the profitable use of relationships and correlations among relevant parameters. To have a reliable, scientifically informed explanation, it is necessary to understand, at least at an initial level, the consequences of the postulated hypothesis and evaluate its consistency with previous knowledge from the same field. Additionally, seeking a reliable conclusion from a set of data requires awareness of the existing relationships between the data and theoretical notions, as well as an evaluation of alternative conclusions that can be derived. This approach requires a deep scientific understanding of the theories serving as background knowledge.

Co-creation of knowledge involves ongoing collaboration, sharing goals, experiences, needs, constraints, and co-evaluation of the usefulness of obtained outputs. It also requires non-superficial expertise in relevant scientific theories, procedural aspects of research, inferential procedures of the scientific process, and meta-inferential aspects aimed at establishing the required level of acceptability of inferences. While citizens can collect relevant data, make observations, and produce relevant information, assessing the integrity of data, the quality of the retrieved information, and the explanations and conclusions derived from those observations requires specialized skills (Ghinea, 2019).

It is difficult to imagine how a lay citizen could independently carry out such steps, unless they possess expertise comparable to that of a researcher, gained through years of training. Additionally, scientific research projects are often interdisciplinary because real-world problems are complex, and so necessitates the construction of a common perspective among different disciplines. However, this is a hard task even for experienced researchers, as disciplinary training does not make researchers “all-rounders”. In these situations, barriers separating citizens and scientific practices might be even higher and more difficult to overcome.

5. Conclusions

While CS constitutes a substantial step towards the democratization of science (Dorato, 2020), the acquisition of knowledge and new skills for society, the building of scientific awareness, and the provision of elements to improve decision-making and the activation of more evidence-based policies, the idea of allowing supposedly non-expert citizens to generate knowledge at all stages of the scientific process raises many doubts.

If it is merely a matter of applying already known scientific theories to specific contexts, and the aim is to find the best solution to the problem under investigation, then the epistemic goal may be limited. In this case, it is more important to achieve a “knowhow" that has the connotations of scientificity (i.e., systematic explanation of why it works, reliability in relevant situations, replicability over time and under the same conditions, etc.) rather than a true deep scientific knowledge. However, if we raise the epistemic goal to knowledge that goes beyond the limitations of known theories, for example by including additional parameters (such as in agribusiness, where the healthy growth of a plant could be considered within a framework that includes the detailed chemical composition of the specific soil, the specific quality of the water used, the air, etc.), citizens must be deeply literate.

Nowadays, Citizen science and, in general, participatory projects are pedagogical, sociological, organizational, and political approaches to research. However, if we do not confine them within reasonable boundaries of what laypeople can actually do for science, they can be hardly charged of epistemic value. Indeed, when the goal of constructing scientific knowledge comes into play, socio-organizational formalizations cannot neglect epistemic issues CS naturally raises. Arguably, disregarding an epistemic /epistemological approach—the one that guarantees the status of scientific knowledge to the outputs of research— might yield a debasing of science (and scientific culture) to a kind of "night in which all cows are grey". In a time of conspiracy and post-truth theories, this is an undesirable outcome that only the acquisition of a great level of awareness—both by citizens and the leading organizers of participatory research—can avoid.

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