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Citizen Science: Past, Present and Future of Public Engagement in Scientific Research

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Abstract

When the relationship between science and society takes on a more prominent role, initiatives that allow greater engagement and dialogue between both parties become increasingly relevant. In this context, the past decade has seen an enormous growth of a practice known as citizen science as a form of public participation in scientific research that promotes the faster advance of scientific knowledge and contributes to greater collaboration between science and society. This article presents a brief overview of the main aspects of citizen science, how this practice emerged and how it mobilised the engagement of society in the past, particularly by analysing examples related to biodiversity recording and outlining the current situation in Portugal. It includes some suggestions for developing future actions in this field, particularly studies that analyse the motivations to participate in scientific research, allowing for a more open and shared science.

Keywords

citizen science, public engagement, motivations, research, history

A Ciência Cidadã: Passado, Presente e Futuro do Envolvimento Público na Investigação Científica

Resumo

Numa altura em que as relações entre ciência e sociedade adquirem cada vez mais protagonismo, iniciativas que permitam um maior envolvimento e diálogo entre ambas as partes ganham cada vez mais destaque. Neste contexto tem-se assistido a um enorme crescimento, ao longo da última década, de uma prática conhecida como ciência cidadã que, pelo facto de constituir uma forma de participação pública na investigação científica, potencia o avanço mais rápido do conhecimento científico, contribuindo para uma maior colaboração entre a ciência e a sociedade. Apresenta-se aqui um breve apanhado das principais características da ciência cidadã, de que forma esta prática surge no passado, mobilizando o envolvimento da sociedade daquele tempo, analisando, em particular exemplos relacionados com o registo da biodiversidade, e traçando algum do panorama atual em Portugal. Deixam-se algumas sugestões para o futuro desenvolvimento de ações nesta área, em particular estudos que analisem as motivações para participar na investigação científica, permitindo abrir portas a uma ciência mais aberta e partilhada.

Palavras-chave

ciência cidadã, envolvimento público, motivações, investigação, história

1. Introduction

When we talk about the relationship between science and society, the growing interest in initiatives focused on the engagement of the public in scientific activity has been remarkable over the last decades. That reflects a change from the previous emphasis, mostly on issues of public understanding of science. The concept of open science, for example, is increasingly prominent nowadays, especially in the European landscape. For instance, the European Commission has given great emphasis to the implementation of open science in the European Union framework programme for research and innovation, Horizon 2020 (2014–2020; European Commission, n.d.), promoting the engagement of citizens in science and technology decisions aiming to improve the alignment of the goals, processes and outcomes of research and innovation with the values, needs and expectations of society.

The "citizen science" movement has assumed great prominence over the last 2 decades and is part of the open science scenario.

This work aims to present an overview of citizen science, with a brief description of the past and present in Portugal, highlighting citizen science practices related to biodiversity and addressing some examples of engagement dynamics used over time. It includes suggestions for future studies to understand how society's engagement in this practice can be improved so that science is effectively more open to society.

2. What Is Citizen Science?

There is no single, consistent definition for the concept of citizen science, as it is a practice that takes on multiple aspects. The term emerged in the 1990s through two different epistemological directions: that of Alan Irwin (1995) and Rick Bonney (1996, as cited in Bonney et al., 2009). Irwin (1995) defines citizen science as an approach to support a more democratic and participatory science, developing concepts of science citizenship and stressing the need to open science policy processes to the public. Bonney (1996, as cited in Bonney et al., 2009) describes it mainly as a tool used by professional scientists in which citizen volunteers contribute to science through data collection. Later, in the white paper on citizen science in Europe, the term is defined as "the involvement of the general public in scientific research activities in which they actively contribute to science with their intellectual effort, their knowledge or their tools and resources" (Serrano-Sanz et al., 2014, p. 8).

Citizen science is essentially an approach to answering key research questions through the voluntary engagement of citizens in the various stages of the scientific process, from the research project design (through the definition of research questions) to the dissemination of key findings and conclusions, to the collection, interpretation and discussion of results.

Citizen science projects are conceived in multiple ways, so there is an effort to categorise them. For example, Wiggins and Crowstone (2011) categorised them according to the project objectives, the activity type and technology use. However, most authors

divide project typologies according to the degree of engagement and the type of scientific tasks performed by the volunteers participating in the project (e.g., Bonney et al., 2009; Haklay, 2013). In this type of classification, based on the type of volunteer engagement, projects can be classified according to the following types: *contributory* (usually designed by scientists where the general public contributes data); *collaborative* (usually designed by scientists where members of the public contribute data and help refine the project design, analyse data or disseminate results); and *co-created* (designed jointly by scientists and members of the general public where some of the public are actively involved in most or all steps of the scientific process). In a paper from 2012 (Shirk et al., 2012), two other categories were added: *contractual* (where communities ask scientists to conduct specific scientific research and report the results) and *collegial* (where citizens conduct research that creates scientific knowledge separately from the scientific community).

Citizen science thus takes on several facets, including raising new research questions and co-creating new scientific knowledge. Volunteer participants acquire new knowledge and skills and a deeper understanding of scientific work, which enables new forms of scientific culture. In this collaborative and transdisciplinary scenario, it is thus important to understand how to improve the interactions between science and society to allow more open and participatory research.

3. Engagement in Citizen Science Practices

One of the main challenges in citizen science is understanding what drives public engagement in citizen science and how this engagement can be maintained over time. However, this is not an easy task. Studies such as Raddick et al. (2010) or Rotman et al. (2012), to name but a few examples, identify motivation categories and factors for contributing to a project. Whereas Nov et al. (2014), for example, explore motivation as an underlying factor for both the quantity and quality of contribution in citizen science projects, West et al. (2021) offer an interesting literature review on voluntary participation in citizen science.

Generally, self and more altruistic motives are often identified as important to participants (Kragh, 2016). Motives for their selves may include personal interest in the topic under investigation, for example, interest in chemical structures, biodiversity or the environment; a desire to learn more about the topic; or a desire to discover something new such as, for example, new species or new galaxies. Depending on the type of project and the form of participation, there may be other reasons for participation. For example, participation may provide participants in environmental projects opportunities for entertainment or for spending time in nature. Motivations related to pursuing a professional career, such as volunteering to gain experience to include in the curriculum or the opportunity to collaborate with an institution in which one wishes to work, are rarely mentioned. When they are, they refer to responses from students or young people (Johnson et al., 2014). Many of the participants in citizen science projects have their own motives for getting involved in the projects. However, altruistic motives are, in many cases, more

influential than their own. An important altruistic motive for the participation in citizen science projects is the willingness to contribute to science, a motive unique to citizen science and that distinguishes it from other opportunities for voluntary participation. Other altruistic motives, such as being able to contribute to a cause or the feeling that it is important to help, are also significant for many. Participants in citizen science projects in environment-related areas, such as biodiversity monitoring, are often altruistically motivated to participate because they are concerned about the environment and feel it is important to help conservation efforts. However, have the motives for participating in a citizen science project always been the same throughout the history of this practice?

4. The Pertinence of Studying the Past of Citizen Science

Thanks to the proliferation in recent years of citizen science projects in several countries, this practice is often referred to as recent. However, the engagement of citizens without specialised training in science is far from being a new phenomenon. The history of science provides several examples showing that the first modern scientific data were mostly obtained by amateurs, namely members of the clergy or aristocrats, who had the time and financial means to collect information about the natural world (Silvertown, 2009). In reality, it is important not to lose sight of the recent rise of science as a profession. The term "scientist" is only coined in the first half of the 19th century[1], and only decades later (or, in many countries, throughout the 20th century) is there an effective professionalization of scientific activity (Haklay, 2013; Vetter, 2011). Similarly, the engagement of the non-specialist public in large-scale initiatives to collect scientific data also has a long history. For hundreds of years, groups of people without specific scientific training have made observations and records about the natural world, including collecting information about animal and plant species distribution, meteorological data and observations of astronomical phenomena. Associations or government entities often centralise these records (e.g., Carolino & Simões, 2011; MacGregor, 2018; Roy et al., 2014). Thus, studying the history of citizen science not only helps to understand how this practice has taken different contours over time but also helps to understand how the relationship between science and society has developed and what has been motivating society's engagement in science.

One of the areas where there are most examples of public engagement in science is biodiversity recording. For centuries, countless people have shown motivation and interest in identifying and documenting the occurrence of animals and plants, in other words, in recording biological data. A biological record is a point on a map showing that a particular species or organism was found in that place on a particular date. However, despite this simplicity, making a biological record is an incredibly diverse activity which involves thousands of people worldwide for centuries. There has been a long tradition of amateur naturalists collecting specimens, recording their observations in journals, and

[1] In response to a challenge from the poet S. T. Coleridge, in 1833, William Whewell invented the word "scientist". Previously the terms in use were "natural philosopher" and "man of science".

becoming specialists in specific habitats or taxa since the 17th century (Miller-Rushing et al., 2012). Some surveys point to historical traditions regarding the systematic collection of observations and information by society, including millennial records documenting natural phenomena over time. The Audubon society's Christmas bird count, which began in 1900 and continues to take place annually at hundreds of sites in the United States and Canada, is commonly noted as one of the earliest such initiatives (Dunn et al., 2005). There are, however, other examples. In China, citizens and officials have recorded locust outbreaks for at least 3,500 years (Tian et al., 2011), while in Kyoto, Japan, we find records of cherry trees blossoming over 1,000 years ago (Aono & Kazui, 2008).

While the long history of voluntary engagement in the biological recording is widely acknowledged to have played a critical role in science and decision-making, it is unknown in many countries. Thus, it is worth trying to understand what kind of calls were made for society's participation and, if possible, their motivation to participate.

5. Some Past Examples of Citizen Science in Portugal

Although they do not seem very frequent, there are historical examples of voluntary engagement in the biological record in Portugal. Aristocrats with a fondness for nature observation which, in their spare time, contributed to the biodiversity record (Felismino, 2016), or others who, besides their governance duties, dedicated some of their free time to natural history (Sousa, 1861). However, no thorough study of the history of citizen science in Portugal has ever been conducted, and the history of amateur biodiversity monitoring practices has not been systematically traced. Revealing the history of biological recording in Portugal is like telling the history of citizen science in biodiversity monitoring. It discloses how communities of amateur naturalists were formed and evolved throughout the 19th and 20th centuries to understand when and how the public was called to engage and participate in biodiversity monitoring practices. Telling this story is thus of the utmost importance to help explain why citizen science and non-expert biodiversity monitoring practices are still residual in Portugal compared to other countries. In other words, looking at the examples from the past can help to understand the reason for the still low engagement and motivation to participate in citizen science projects at present and help enhance participation in the future.

In an attempt to reconstruct part of the history of citizen science in Portugal, a study is being developed to examine the network of volunteer collaborators in recording animal biodiversity and how information circulated between collectors, amateur naturalists and specialist naturalists. When surveying the historical archives, particular attention is given to the catalogues and publications held in the National Museum of Natural History and Science, now part of the University of Lisbon. The documentation in that museum provides important data, such as instructions for data collection and information about the collectors of the specimens. Furthermore, it shows what kind of appeals were made to participate in the biological registry and what motivations were behind the participation of some members of the society.

José Vicente Barbosa du Bocage (1823–1907), director, from 1858, of the Museum of Lisbon (the institution that became the current National Museum of Natural History and Science), published, in 1862, *Instrucções Praticas Sobre o Modo de Colligir, Preparar e Remetter Productos Zoologicos Para o Museu de Lisboa* (Practical Instructions on How to Collect, Prepare, and Send Zoological Products to the Museum of Lisbon; Bocage, 1862). With this publication, the museum director appealed to individuals' collaboration to help expand his zoological collections. Bocage (1862) mentions that:

> Portugal is today the least known and explored of all the countries of Europe. Of its Fauna, only very few rare fragments are known. In the richest and most complete museums, in the best collections of private individuals, one scarcely sees one or another specimen collected from our land. Even our old museum was, at this point, one of the least privileged. We believe it is time to end this disgrace, which, more than anything else, denounces our backwardness and obscurantism to foreigners. It is time to study for ourselves what is ours and to collect in the manner prescribed by science the documents that should serve as a basis for the history of natural productions of our country. (p. 8)

The director states that he would have eventually abandoned the project of expanding the museum's collections if he had not expected much help from many of his fellow citizens. Therefore, he addressed his instructions to those who wished to help the museum. It is very interesting how this document addresses the general population and calls for the collaboration of all those interested in collecting zoological specimens, disregarding any previous experience as an amateur naturalist:

> to collect the natural products of the area in which one resides, entertain the idleness of country life with occupations that lighten the hours and elevate the intelligence, study nature, and seek to understand the great work of creation by spelling out some of the pages of its history, one does not need to be a naturalist by profession, nor a scholar graduated from universities and academies. To start, a few indications on how to look for and prepare the objects one wishes to collect suffice; then, the repetition of the excursions and research, the experience of each day, and the trials and observations themselves will develop aptitudes, we might say almost instincts, of a true naturalist. (Bocage, 1862, p. 9)

This excerpt from *Instrucções Praticas Sobre o Modo de Colligir, Preparar e Remetter Productos Zoologicos Para o Museu de Lisboa* (Bocage, 1862) is a testament to what we might call a 19th-century call for everyone to become citizen scientists.

The strategy to encourage the population to participate underlines the notion of recognition outside the same official framework of state officials: "we reckon that other people who visit the overseas territories or live there permanently (...) will not refuse to contribute with whatever donations they can get, and that will bring their names to public recognition" (Bocage, 1862, p. 11).

It also highlights the contribution to the country's progress:

> the galleries of the museums of Europe abound with the donations of men who are strangers to science but who are not indifferent to the prosperity and intellectual advancement of their country. We do not believe that the qualities and feelings that in other eras and under the influence of other ideas have made us great and placed us at the forefront of world civilisation are today the exclusive appanage of other peoples. (Bocage, 1862, p. 11)

It is interesting to note the use of recognition to attract and motivate participation, a technique currently used in citizen science practices. In fact, and although some of the names that contributed specimens remain unknown because it is not possible to find information about who they are, the truth is that the recognition of their contribution is forever associated with the museum's biological records.

The success of the strategy implemented by Bocage can, to some extent, be inferred from a report he published in 1865 (Bocage, 1865). He received specimens from about 24 collaborators from different parts of the country. The region with the most collaborators was Coimbra. These collaborators were studying or teaching at the university and, in some cases, were young people striving for an academic career. The second region with the most contributors was Setúbal, a coastal city traditionally linked to fishing and with an important seaport (Gamito-Marques, 2018). It is worth noting that, except for the collaborators from Coimbra, who were actively pursuing an academic career, those who contributed specimens to the museum did not have a main scientific occupation. It would be worthwhile in the future to delve deeper into the reasons and motivations that led to their participation and engagement.

Besides the documentation analysis mentioned above, old publications are also being analysed. These provide examples of calls made by academics for the population's contribution to science, not only through the biological record but also through wider contributions such as correcting inaccuracies. In the 1896 book on the birds of the Iberian Peninsula (Paulino d'Oliveira, 1896), one of the classic works of Portuguese ornithology, Manuel Paulino d'Oliveira (1837–1899), professor at the University of Coimbra and director of its museum, includes the following passage:

> if hunters take note of any faults or inaccuracies they may find in this work, based on their observations, and use them for their own col[lections] or send to museums the new or r[are] spe[cies] they find, hunting will become more attractive to them, and they will greatly help future ornithologists. (p. 126)

Nowadays, some citizen science projects in Portugal are trying to find ways of involving hunters and fishermen in biodiversity monitoring, so it is worth bringing to light the results of the engagement of these communities in the past so that today's communities feel a greater drive to contribute to scientific development.

6. The Present of Citizen Science in Portugal

As we have seen from the previous examples, citizen science in Portugal is far from being a new practice. However, it still has little projection compared to what happens in other countries. Nevertheless, it has gained more momentum over the last decade.

In the Portuguese case, as in many other national contexts, organising and gathering efforts around the community that already promotes citizen science initiatives is important. It is also essential to create a broader plan to disseminate the potential of citizen science, both for greater and faster progress in scientific research and for a closer relationship between science and society at large. In 2017, a first step was taken with the organisation of the first "Encontro Nacional de Ciência Cidadã" (Portuguese Citizen Science Meeting), promoted by the then Secretary of State for Science, Technology and Higher Education. This first meeting sought to bring together for the first time the communities involved in citizen science initiatives in Portugal to highlight experiences, pathways and examples of actions in this area and launch the debate for the creation of a national strategy for citizen science. The "2.º Encontro Nacional de Ciência Cidadã" (2nd Portuguese Citizen Science Meeting) was held in 2019. It was promoted by several national institutions and aimed at bringing together all involved in citizen science initiatives interested in learning more about this topic from inside and outside academia. It also sought to debate the creation of a citizen science network in Portugal and a national portal for the dissemination and aggregation of projects and initiatives in this area. Although not yet formalized, the Portuguese Citizen Science Network (CC.pt) was created. It meets regularly with all members interested in the subject, inside and outside the academy, and has working groups in operation. In 2021, the CC.pt network promoted the "3.º Encontro Nacional de Ciência Cidadã" (3rd Portuguese Citizen Science Meeting), which motto was "building bridges for a participatory science", and is preparing to launch a platform on which it will be possible to view citizen science projects and initiatives taking place in Portugal.

The network is also developing the mapping of ongoing citizen science initiatives in Portugal. However, in a non-exhaustive survey conducted in 2015 (see more detailed information in Conceição & Luís, 2021) and upgraded in 2019 (Piland et al., 2020), it is possible to see that, in Portugal, citizen science projects follow a global pattern, that is., are mostly *contributive* and in the areas of environment and biodiversity (e.g., *BioDiversity4All*, *Invasoras.pt*, *GelAvista*, *Lixo Marinho*). There are also some examples in health (e.g., *Gripenet*, *MosquitoWeb*) and astronomy (e.g., *Sun4All*, *Caçadores de Asteroides*; see Table 1). Some projects are also emerging in the humanities and social sciences (e.g., *Memória para Todos*, *Histórias de Vida*, *Novos Decisores Ciências*), but in smaller numbers than in the other areas. It should be noted that some of the projects stem from the collaboration with international platforms (e.g., *Biodiversity4All*, *Portugal Aves*, *Gripenet*), and it is also worth mentioning that some projects are particularly aimed at the school public (e.g., *Caçadores de Asteroides*, *MEDEA*, *EduMar*). By allowing the engagement of students in scientific research activities, this type of experience familiarizes them with the typical procedures of science production, contributing, at the same

time, with data for the development of scientific knowledge. It is also worth highlighting the emergence in Portugal, albeit very residual, of citizen science initiatives emanating from civil society or public institutions outside the strictly scientific sphere. An example is the *Histórias de Vida* (Life Stories) project, launched by the Oeiras municipal libraries to collect and record the stories of people in the community born before 1955 and cross-reference them with local history.

Project	Scientific area	Brief description	Website
BioDiversity4All	Biology/ biodiversity	An online biodiversity platform, accessible to all, with citizens' records of plants, animals and fungi submission	http://www.biodiversity4all.org/
Caçadores de asteroides	Astronomy	A project for tracking asteroids, coordinated by the University of Texas, where schools from around 40 countries participate, including Portugal	http://nuclio.org/iasc/iasc-pt/
EduMar	Biology/ environment	A project to raise awareness through citizen science practices of 4th and 5th-grade students for preserving the sea and its resources	https://www.biodiversity4all.org/projects/edumar
GelAvista	Biology	A programme that counts on citizen volunteers to obtain data to monitor the populations of gelatine organisms (such as jellyfish) on the Portuguese coast	http://gelavista.ipma.pt/
Gripenet	Health	Monitors the seasonal influenza epidemic through the internet with the voluntary participation of citizens	http://www.gripenet.pt/
Histórias de vida	History	A challenge from the municipal libraries to rediscover the municipality of Oeiras, giving voice to its senior inhabitants to share with the community their stories and memories	http://historiasdevida.cm-oeiras.pt/
Invasoras.pt	Biology	It aims to alert to the problem of biological invasions, to make invasive plants known at a national level and stimulate the active participation of the public both in mapping these species and in control and dissemination activities	http://invasoras.pt/
Lixo Marinho	Environment	This project emerged from the need to produce statistical data and raise awareness about the problem of marine debris. Participants are asked to count and collect marine debris on their beaches	https://lixomarinho.app/
MEDEA	Physics/health	A project to measure electromagnetic fields in the environment, conducted by students from various secondary, vocational and higher education schools in the country	http://medea.spf.pt/
Memória para Todos	History and cultural heritage	This research project invites all citizens to share their personal and family memories of certain historical moments and processes	http://memoriaparatodos.pt/
MosquitoWEB	Health	A project that invites citizens to participate by taking pictures of mosquitoes or by capturing and sending mosquitoes by mail	http://www.mosquitoweb.pt/
Novos Decisores Ciências	Environment	Original research questions co-created between citizens and researchers. In Portugal, a research project on coastal geology commissioned by a group of residents from the Segundo Torrão neighbourhood, Trafaria, Almada, is under development	https://es-la.facebook.com/pg/Torrao2825/posts/
Sun4All	Astronomy	A project to promote astronomy among non-higher education students using a collection of images of the sun	http://www.mat.uc.pt/sun4all/index.php/pt/

Table 1 *Some citizen science projects in Portugal*

Source. Adapted from Conceição and Luís, 2021

Citizen science projects taking place in Portugal (of which only a few examples have been given here) have been increasing every year as this practice becomes more widely known. However, there is still much to be done in studying the implementation and evolution of citizen science in Portugal.

In a survey conducted in late 2016 among the Portuguese scientific community, which results have already been partly reported by Luís et al. (2018), some researchers' lack of knowledge about citizen science or its potential was confirmed. Although the term is no longer completely unknown to many researchers, most see it as more in line with the movement of public awareness of science than exactly as effective public participation in scientific research. Citizen science has gained more prominence at an international and national level. More and more attempts are being made to envisage the future of citizen science. Thus, it is worth understanding the scientific community's perspectives on this practice and the motivations behind creating this type of project by those developing projects involving civil society's participation. Furthermore, given the potential of this engagement of citizens in scientific research, it is also important to understand the real potential of public engagement these projects allow and what motivates society to get involved.

7. The Future of Citizen Science in Portugal

There is not much literature on the motivations for participation in citizen science projects in Portugal. However, there is a study conducted by Tiago et al. (2017) on the influence of motivational factors on the frequency of participation in citizen science activities. This study was based on the analysis of an online survey of participants in the largest platform for recording biodiversity in Portugal, the *BioDiversity4All* platform. The results suggest that working on topics related to the participants' engagement in citizen science initiatives is fundamental to increasing and maintaining their participation. For initial recruitment, especially in countries with a low culture of participation, such as Portugal, external motivation mechanisms may be necessary to ensure higher levels of participation. In the long term, citizen science projects should foster intrinsic motivations, incorporating relationship experiences, capacity building, positive feedback and adapted participation models into the projects.

Understanding what drives society's voluntary participation in citizen science projects is thus key to encouraging their greater engagement and maintaining these projects' long-term sustainability. Participants have diverse motivations, and people from different demographic groups will have different motivations. Further understanding how motivations differ between groups is therefore important so that the implementation of citizen science actions can improve engagement with the communities with which they work. It requires further research to understand participants' different motivations better, track how motivations change throughout the participation process and improve society's engagement in the scientific process.

8. Final Considerations

Much has changed over time regarding the approximation between science and society, and Portugal is no exception. Citizen science projects, not necessarily a novelty as seen by the examples presented, are one of the most interesting developments in this approximation movement. In particular, they configure an approach based on the more active participation of citizens in scientific practice and, ultimately, in exploring new forms of co-creating scientific knowledge in a shared process between scientists and non-scientists.

In Portugal, the experiences of citizen science are growing. Although they still adopt an essentially contributive model, it is expected that, given its huge potential for society's engagement, they will adopt a more collaborative nature. Furthermore, so this practice can effectively take more collaborative characteristics and involve more members of society in the future, it would be interesting to develop studies to understand better what motivates the participation of non-scientists in science, opening doors to a science that is increasingly open and shared.

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