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Characteristics of Spanish citizen participation practices in science

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Abstract

A new regime of science production is emerging from the involvement of non-scientists. The present study aims to improve understanding of this phenomenon with an analysis of 16 interviews with Spanish coordinators of participatory science practices. The results indicate a majority of strategic and captive publics and point to communication as a key tool for the development of successful practices. Five key elements of the degree of integration required to develop a citizen participation in science practice were analysed: derived outputs, level of participant contribution, participation assessment, practice replicability, and participant and facilitator training. Proposals for strategies to remove barriers to citizen participation are the study's principal contribution.

Keywords

Citizen science; Participation and science governance; Public engagement with science and technology

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Context

During the past decade, the involvement of non-scientists in science has engaged an increasing number of researchers in a new regime of science production. Greater citizen involvement in research processes and knowledge production is valuable to democratic societies, a premise supported both for reasons of philosophy [Wylie, 2015] and global strategic policy [Hockfield, 2018]. There is a general trend towards the broader, more inclusive and active participation of different societal groups in scientific projects, as can be seen in the tremendous diversity of research and coordination activities worldwide [Mejlgaard et al., 2019; Hockfield, 2018].

In the last few years, a number of changes have occurred in Spain's approach to integrating science and society. However, the inclusion of non-scientists in science production is not as developed as in some other European countries [MoRRI Consortium, 2018]. Currently, the involvement of scientists in participatory projects is not included as an evaluation criterion, hence citizen involvement is limited, and the organisational landscape enabling the engagement of citizens is not well

developed [MoRRI Consortium, 2018]. Nevertheless, the trend is to align Spain's strategy with European guidelines through greater inclusion of society in the scientific process, as we can see from the various calls to promote citizen science projects [Hockfield, 2018].

Despite this, much disagreement remains about how this non-scientific involvement should be conducted, with different understandings of the nature of participation in science and the kind of stakeholders that should be engaged in the research process.

1.1 What is citizen participation in science?

Citizen participation can be understood as citizen involvement in public decision-making [Baum, 2001]. Different conceptions of "citizens" and "participation" exist, however. Participation may involve observation, consultation or production in science-related issues, research projects or political decisions. Most importantly, the citizen participation concept denotes remedial efforts to involve inactive citizens or strategic groups of people in decision-making activities [Baum, 2001]. It thus appears that science is no exception to the broader participation imperative placed on our contemporary democracies [Godden, 2017].

Similar approaches regarding this relationship between science and society are found under the labels "citizen science", "public participation" or "social participation in scientific research" [Kullenberg and Kasperowski, 2016]. These concepts appear almost simultaneously in two areas: social sciences and natural sciences [Kullenberg and Kasperowski, 2016].

In natural sciences, these terms have more often been reserved for data collection and volunteer assistance [Bonney et al., 2009], whereas in social sciences they refer to representative stakeholder engagement in policy processes [Kullenberg and Kasperowski, 2016]. At the same time, the democratisation of knowledge and recent surge of new technologies opens up opportunities for the co-creation of knowledge and innovation through public participation [Stilgoe, Lock and Wilsdon, 2014].

In the current literature, "citizen science" covers a diversity of forms of non-scientist participation (individual citizens, non-governmental organisations, groups of patients, etc.) for the production of scientific knowledge and good science governance [Cooper and Lewenstein, 2016; Eitzel et al., 2017]. Thus, all these society-science approaches encompass any form of active, non-scientist participation in the process of research to generate science-based knowledge, from setting research agendas by asking research questions, to collecting data, analysing results and contributing to decision-making [Bonney et al., 2009; Lewenstein, 2004; Lidskog, 2008; Schrögel and Kolleck, 2019].

1.2 Stakeholders involvement in citizen participation in science

Citizens participating in science may be individuals, organised communities such as civil society organizations (CSOs), or even companies or professional associations. When using the term "public" or "citizen", it is important to consider

that we are actually talking about "multiple publics" [Besley and Nisbet, 2013]. Therefore, a participatory process in science needs a selection of strategic groups of people depending on the objectives of the practice.

The principal goal of many citizen participation science practices is not the production of scientific output. Rather, the first objective often consists of collecting data to provide evidence to support the proposal of an operational solution, influence political decision-making, or launch legal processes to solve a problem [Kullenberg and Kasperowski, 2016]. Some of these initiatives emerge from problems identified by communities or CSOs, often related to environmental issues of pollution, health hazards, species conservation, water and air quality, or draining of natural resources [Brulle and Pellow, 2006; Leung, Yen and Minkler, 2004; Macey et al., 2014]. However, previous studies have revealed that Spanish CSOs mainly participate in science within one single research moment and that they are unaware of their own potential [Llorente, Revuelta and Carrió, 2021]. Even though these initiatives emerge from outside scientific institutions, they rely on scientific procedures for collecting, validating, analysing and interpreting data [Macey et al., 2014; Ottinger, 2010], and scientific content is often co-produced between professional scientists and citizens [Kullenberg and Kasperowski, 2016].

Other examples of citizen participation in science projects add an educational objective to the scientific one. Some of these initiatives aim to improve scientific literacy, increase scientific knowledge in a specific field, or even construct a scientific citizenship [Árnason, 2013; Davies and Horst, 2016]. These types of objectives are found in top-down projects, initiatives proposed by the establishment that seek to include the lay public in the research process [Powell and Colin, 2009]. Thus, students, schools and the educational community are one of the publics most involved in these participatory approaches. However, given that student participation is rarely voluntary, but rather the result of agreements with teachers and schools, students can be considered a "captive public" [Fayard, 1987; Mitchell et al., 2017].

Most participatory projects, therefore, tend to pursue multiple objectives: scientific, socio-political and, often, educational. This should be directly related with de diversity of stakeholders involved in such processes and, therefore, taking representation into account during the conceptualization phase. However, participants in this kind of processes rarely represent a wide range of groups, interests or perspectives [Ott and Knopf, 2019]. Special efforts are therefore necessary to recruit participants and design processes in which diverse participants are similarly represented [Baum, 2015] in order to develop collective and integrated knowledge among scientists and other stakeholders included in the research process [Cornell et al., 2013; Jacobi et al., 2017]. Therefore, it is necessary to analyze to what extent the strategic groups to which the activity should be directed are clearly identified, as well as their possible interests and perspectives.

1.3 Communication role in participatory practices

One of the main changes in this new scenario of science production is the role of communication. The participation, negotiation and public communication mechanisms are tools that allow stakeholders to build trusting relationships and

maintain the dynamics of the research process. In short, the communication model needed to contribute to participatory processes in science places communication and dialogue as the main tool for interaction between actors [García Marzá, Fernández Beltrán and Sanahuja, 2017]. It also places greater focus on the factors that determine an individual's engagement with communication and new information [Longnecker, 2016].

The traditional science communication is mostly unidirectional, thus to carry out such participatory processes it is necessary to go beyond the "deficit model" [Alcíbar, 2015; Brossard and Lewenstein, 2010; Perrault, 2013]. In participatory approaches this model coexists with others that offer a greater interaction such as the "dialogue model" that conceives communication as a two-way flow between science and the public [Brossard and Lewenstein, 2010; Smallman, 2018]. However, despite the bi-directionality, in this model science is still considered as a fixed knowledge without cracks towards which the public must move to engage with [Alcíbar, 2015].

On the other hand, the "deliberation model" [Horst and Michael, 2011] is based on establishing channels so that the public can achieve a critical understanding of the scientific phenomenon and, therefore, can question and respond to the pros and cons [Horst, 2008]. In this model, scientific knowledge and its dissemination continue to matter, but more emphasis is placed on how that knowledge is socially used.

To carry out successful participatory practices, much effort has to be invested in establishing fruitful relationships with the different stakeholders involved. Especially with higher levels of participation, the need for direct engagement between scientists and the public increases [Haklay, 2013]. Such processes require continuous two-way communication to establish, maintain and strengthen this engagement [Trench, 2006]. Communication can even be the basis for the effective performance of citizen participation projects focused on either deliberation [Ott and Knopf, 2019; Roberts, 2004] or science governance [Hagendijk and Irwin, 2006].

Although all the above-mentioned models involve different communication actions, they have coexisted over time and continue to do so today. The different communication models are complementary and enrich each other. Thus, without a more informative communication it is difficult to establish a real and contextual dialogue. Therefore, there is a need to further explore the communication role in current participatory processes.

1.4 Key requirements

From the literature and our personal experience, the authors have identified four key requirements for the development of effective citizen participation practice: derived outputs, level of participant contribution, participation assessment, and practice replicability.

Derived outputs. Given that scientific output is frequently not the only objective of this type of citizen participation projects, scientific results are not always published in the traditional way (i.e. in scientific journals) and may therefore fall

outside the scope of scientific output and scientists' evaluations [Kullenberg and Kasperowski, 2016]. When planning a science participatory process, these other derived outputs must be considered (policy briefs, educational material, legislation, informative material, etc.). However, scientists may be poorly motivated to participate in these types of activities since they are not considered as part of the researcher's routine practice and still are not professionally recognised [Besley, Dudo et al., 2018; Merino and Tarhuni Navarro, 2019].

Level of participants contribution. The diversity of the participative practices can be classified along a spectrum from minimal citizen engagement to total citizen commitment as proposed in Arnsteins' ladder of participation [1969]. Thus, social participation in science can be found from participating in crowd-sourcing data collection programmes to co-construction of knowledge and research questions through deliberative processes [Schrögel and Kolleck, 2019]. Haklay [2013] described four typologies to classify citizen participation in science, which are summarised in Table 1:

Table 1. Levels of citizen participation in science proposed by Haklay [2013].

Level	*Citizens' role*	*Description*
Level 1. Crowdsourcing	As sensors (volunteered computing).	Participation is limited to the provision of resources, and cognitive engagement is minimal.
Level 2. Distributed intelligence	As basic interpreters (volunteered thinking).	Participants are asked to take some basic training and then collect data or carry out a simple cognitive activity.
Level 3. Participatory science	In problem definition and data collection.	Participants take part in problem definition and data collection, but require expert assistance to analyse and interpret the results.
Level 4. Collaborative science	In problem definition, data collection and analysis.	Participants can choose their level of engagement and may be involved in the analysis and publication or utilisation of results.

The categorization described by Hacklay focuses mainly on the processes of scientific production and not in its governance. So, it does not contemplate a purely deliberative citizen participation (e.g., debates around legislation or decision-making in scientific-technical fields). Of course, a deliberative approach is necessary at Hacklay's levels 3 and 4, at least to define the problem and/or during the analysis of the results. Therefore, a mainly deliberative activity demands a similar cognitive engagement to the one included in those levels. Perhaps, such kinds of activities fit more at level 3 since participation does not occur throughout the research process. Identifying the level (or levels) of expected participants' contribution is crucial when planning a participatory approach.

Participation assessment. In a participatory process, the evaluation of such participation should be one of the central elements. However, despite the investment of citizen participation in science activities, there is still a lack of consistent evaluation criteria for systematic assessments [Haenssgen, 2019]. For this reason, in many of these processes it is never known if the participation has been successful or not and/or if the multiple objectives of the project have been achieved [Jensen and Holliman, 2016].

Practice replicability. Like any scientific knowledge creation process, replicability is a key element. The participatory methodologies and processes designed for certain projects should be capable of being scalable to other contexts, themes or localities. This is especially useful to take action to avoid duplication of resources and effort, and establish transparent procedures for using the findings of previous, similar projects [Rasheed and Abdulla, 2020]. Dissemination of these processes and derived knowledge may be useful to decrease "participatory fatigue" caused by a constant demand for community consultation and engagement without an adequate return [Hayward, Simpson and Wood, 2004; Porlezza, 2019].

All this supports the need for exploratory research to improve understanding of how participatory practices are being carried out and make future recommendations for encouraging effective citizen participation. In this study, we address citizen participation in science in the Spanish context and explore the degree of incorporation of these four key requirements, posing the following research questions:

RQ1: Who are the main stakeholders involved in Spanish citizen participation practices?

RQ2: What is the role of communication in these practices?

RQ3: To what extent are the 4 key requirements (derived outputs, level of participants' contribution, participation assessment and practice replicability) incorporated in current citizen participation practices?

Methods

To answer these questions, we conducted 16 semi-structured interviews with coordinators of citizen participation practices carried out in Spain between 2015 to 2017. The selection criteria were developed considering the diversity of levels of citizen participation, based on the categorisation proposed by Haklay [2013].

An advisory board comprising 10 members of 10 Spanish scientific culture units, which are structures formally recognised by the Spanish government and based at universities and research centres [Capeáns, López and Remiro, 2012], was constituted. These units were key to the study due to their local knowledge of the research reality in different parts of the country and, in particular, their ability to identify potential citizen participation practices for inclusion in the study. The scientific culture units were chosen taking into account their geographical distribution and previous working connections (Table 2).

The advisory board collaborated with the research team throughout the study regarding the definitions of the "citizen science" concept, study dimensions, revision of the semi-structured interview scripts, and selection criteria of the interview candidates. We also relied on their experience during the discussion of the results, thus ensuring the reliability of the interpretations.

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Table 2. Entities to which the advisory board belongs.

University or research centre	*City*	*Autonomous community*
University of Seville	Sevilla	Andalusia
University of Córdoba	Córdoba	Andalusia
University of Zaragoza	Zaragoza	Aragon
AZTI Tecnalia	Pasaia, Gipuzkoa	Basque Country
Human Evolution National Research Centre (CENIEH)	Burgos	Castile-León
University Jaume I	Castellón de la Plana	Valencia
Polytechnic University of Valencia	Valencia	Valencia
Polytechnic University of Madrid	Madrid	Madrid
University Carlos III	Madrid	Madrid
Seneca Foundation	Murcia	Murcia

appropriate measures to comply with regulations on the protection of natural persons with regard to the processing of personal data and the free circulation of these data (GDPR) included in the Spanish law: Organic law 3/2018, of December 5, on the Protection of Personal Data and guarantee of digital rights (LOPDGG). The Institutional Commission for the Ethical Review of Projects (CIREP) is the collegial organism that assesses and tracks research projects coordinated by the Universitat Pompeu Fabra that include research on human beings, use human biological samples and use personal data (health and clinical data). As none of these case applies to this research project, a specific ethical report has not been required.

2.1 Sampling

First, we agreed with the advisory board an operational conceptualisation of a "citizen participation in science practice" to begin with the selection. For this study: a citizen participation practice is the active involvement (opinion, data collection, interpretation of results and/or decision-making) of individuals or social groups in different phases of a scientific research project.

Having established the definition, we reviewed the abstracts of the practices funded by the annual Spanish Call for the Promotion of Scientific Culture during the period 2015–2017 to identify those that fitted our concept of citizen participation in science. This call is the principal instrument for projects within the area of science communication and promotion of scientific culture in Spain [López Pérez and Olvera-Lobo, 2017]. It is launched each year by the Spanish Foundation for Science and Technology (FECYT), a Spanish government agency. We broadened the search with a literature review and advisory board knowledge to not focus exclusively on FECYT funded practices and to obtain a more diverse sample. A total of 32 practices fitted our definition.

In a first analysis of these 32 practices, we identified various types according to the body responsible, whether representative of the academic or scientific sector, the business sector, the public administration, or civil society. After taking this and the

level of engagement of the participatory practices into account, we selected a sample of strategic individuals.

Having identified potential interviewees, we sent them an e-mail describing the project and inviting them to take part in an interview, following up with up to three further emails and phone calls to solicit participation from the non-responders. An additional effort was made to contact civil society and public administration coordinators to obtain a more diverse sample. We made contact with a total of 24 coordinators: 18 responded, 2 declining to take part. Interviews were therefore conducted with 16 people (see Table 3).

Table 3. Sample description.

ID No.	*Coordinator profile*			*Practice description*
	Gender	*Occupation*	*Sector*	
1	Female	Researcher	Scientific sector	*Level 2:* Research project on the tiger mosquito and yellow fever mosquito expansion. Participants contribute by collecting and sending mosquito pictures and exact locations through an app.
2	Male	Institutional communicator	Scientific sector	*Level 3:* Project that fosters nanoscience debate between citizens and other stakeholders to reach conclusions and joint solutions for improved legislation.
3	Female	Researcher	Scientific sector	*Level 2:* A participatory space in a museum to promote collective stewardship of research activities (e.g. seismology research project or device development for people with diabetes). Participants contribute by collecting data.
4	Male	Public engagement projects manager	Public administration	*Level 3:* A participatory space in a museum that fosters collaboration between different actors from different fields to build a prototype (e.g. an engineering product, specific software etc.).
5	Male	Researcher	Scientific sector	*Level 3:* Project to analyse and promote "science shops", a vehicle for creating spaces for dialogue and interaction on sustainability between citizens and the scientific community. Participants help identify pressing problems.
6	Male	Researcher	Scientific sector	*Level 4:* Research project on mental health. Participants contribute by helping to elaborate research questions and objectives, acting as study subjects and collaborating in the design of solutions.
7	Female	Manager	Civil society organisation	*Level 2:* Research project on air pollution. Participants contribute by collecting data on urban air quality on their usual routes.
8	Male	Researcher	Scientific sector	*Level 2:* Research project on light pollution. Participants contribute by analysing and categorising satellite images.

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Table 3. *Continued from the previous page.*

ID No.	*Coordinator profile*			*Practice description*
	Gender	*Occupation*	*Sector*	
9	Female	Manager	Scientific sector	*Level 3:* Project to promote end-of-degree projects in collaboration with third sector entities. Participants take part as study subjects or contribute by identifying research questions and objectives, and collecting data.
10	Male	Institutional communicator	Scientific sector	*Level 4:* Research project on air pollution. Participants collaborate by identifying research objectives, in data collection, data processing and results communication.
11	Male	Manager	Public administration	*Level 1:* Research project on climate change. Participants install weather stations in their homes and provide data.
12	Female	Manager	Civil society organisation	*Level 4:* Project to restructure a zoo. Participants collaborate in the identification of elements to improve, in the proposal of solutions and in decision-making.
13	Female	Manager of public engagement projects	Scientific sector	*Level 3:* Research project on the prevention of sexually transmitted diseases. Participants collaborate in the definition of research questions, data collection and communication of results.
14	Female	Manager of public engagement projects	Business sector	*Level 4:* Project to promote collaborative research on environmental issues. Participants collaborate in identifying a problem, collecting data, proposing solutions and communicating the results.
15	Male	Researcher	Scientific sector	*Level 3:* A participatory space in a public library, in which participants collaborate in co-creation activities using technology to increase cultural heritage and knowledge (e.g. developing artificial intelligence algorithms).
16	Female	Researcher	Business sector	*Level 2:* Research project on water pollution. Participants collaborate by collecting data on drinking water quality to develop a community map.

The average age of the interviewees was 45 years (SD = 7.5), and there was an equal distribution of male ($n = 8$) and female ($n = 8$). All the interviewees had completed a higher education degree programme ($n = 16$). Before agreeing to take part, all were informed of the nature of the study and the data processing policies, and freely gave their consent. All the participants were free to answer only the questions they chose to answer and to withdraw from the study at any time.

2.2 Data collection and processing

The research team developed a semi-structured interview protocol (see Figure 1) to answer the stated research questions. One interviewer conducted face-to-face or Skype interviews, according to the interviewee's preference. All the interviews were conducted from June to July 2018. The average interview took an average of

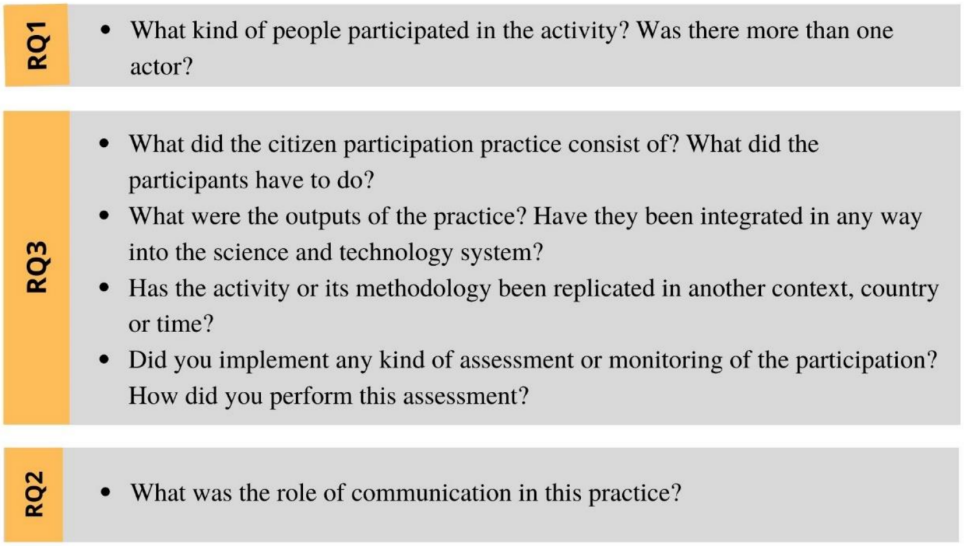

Figure 1. Interview protocol.

42 minutes to complete, within a range from 25 to 73 minutes. Interviews were transcribed and all the transcriptions were reviewed by the authors.

2.3 Data analysis and interpretation

A sequential analysis of the interviews was carried out, and observational notes were included in the transcription of the interviews. Inductive qualitative content analysis was used to analyse the data and interpret its meaning with the support of Atlas.ti (version 8.4) research software. This research method reinforces the systematisation and objectivity of describing and quantifying phenomena [Schreier, 2012], according to which we reduced the data to concepts that describe the research phenomena by creating categories, that is, groups of content that share a commonality [Elo et al., 2014]. Comparing data analysis with different researchers, peer debriefing and member checking were the strategies used to ensure reliability.

Results

3.1 Stakeholders involved in citizen participation practices in science

From the interviews, we identified three kinds of stakeholders involved in citizen participation practices in science; strategic, captive and generic participants. We summarize them in Table 4.

3.1.1 Strategic participants

On 12 occasions, interviewees mentioned groups of people with specific characteristics as participants in the activity. For example, there were mentions of "researchers" (e.g. Interviews 2, 7, 10, 14), "scientists" (e.g. Interview 7), "researcher networks" (e.g. Interview 8), "academia" (e.g. Interviews 1, 15), "universities" (e.g. Interviews 5, 8), and "research centres" (e.g. Interviews 5, 8, 14) as examples of stakeholders involved in the activity.

Table 4. Qualitative results of stakeholder involvement in citizen participation practices in science, analysed through a categorisation system.

Stakeholders involved	*Description*	*Frequency*
Strategic participants	References to concrete groups of people who have some kind of specific characteristic that makes them ideal to be members of the practice.	12/16
Captive participants	References to groups of people who do not decide for themselves (such as students) to participate in the project as stakeholders involved in the practice.	8/16
Generic audience	References to generic groups of people (e.g. the public or interested persons) as stakeholders involved in the practice.	1/16

There were also mentions of other kinds of stakeholders such as "public sector" (e.g. Interview 1), "government" (e.g. Interview 1), "public administration" (e.g. Interview 6), "city council" (e.g. Interviews 7, 10), "politicians" (e.g. Interview 12), or "people with decision-making power within the government" (e.g. Interview 13). There were also some mentions of "citizens" (e.g. Interviews 2, 5, 12), "civil society organisations" (e.g. Interview 1), "citizen associations" (e.g. Interview 5), "neighbourhood associations" (e.g. Interview 15), "patient associations" (e.g. Interview 6) or "NGOs" (e.g. Interview 13) as examples of stakeholders from civil society.

But we also found some references to specific societal actors linked to or interested in the specific activity, such as "private companies" (e.g. Interview 1), "journalists" (e.g. Interview 5), "doctors and health personnel" (e.g. Interview 6), "cyclists and taxi drivers" (e.g. Interview 7), "teachers" (e.g. Interviews 8, 9), or "cultural institutions" (e.g. Interview 10). For example, one interviewee said:

> In our case, we have representatives from academia, the public administration, the library network, library users, local neighbourhood associations and a group of small companies and businesses in the area who have also taken part. (Interview 15)

Despite the diversity of actors mentioned, we have included all these references in the "strategic participants" category because behind all of them there is a strategic selection process to match the audience with the objectives of the practice.

3.1.2 Captive participants

In the course of the interviews, there were 8 mentions of sizeable groups of people who definitely did not themselves make the decision to participate in the project. For example, one interviewee mentioned "actors in the educational world such as teachers and their students" (Interview 1) as the main stakeholders involved in the practice. Similarly, we found references to "schools" (e.g. Interview 7, 14), "students" (e.g. Interviews 9, 10, 13, 14, 16) or "educational community" (e.g. Interview 3). Here is an excerpt from one interview:

> The primary audience is the educational community, that is, teachers and schools. The main bulk is older children, from 12 or 13 years old. But throughout the project they are working with the city council, local associations, businesses, etc., to identify a problem, improve it, and fix it. (Interview 14)

All these references have students as one of the main stakeholders, who are principally involved in data collection (e.g. Interviews 1, 7, 10, 13, 14, 16). However, they are accessed through teachers or schools that decide to participate in the project. Thus, the students are a captive audience [Fayard, 1987] taking part in the activity as part of their educational process and the teachers are schools are considered strategic participants.

3.1.3 Generic participants

One interviewee made reference to generic groups of people as main stakeholders. For example, we found references to the "general public" (e.g. Interview 11) or "any type of interested person" (e.g. Interview 11) without specifying what kind of social groups they had integrated into their practice:

> No, there is no specific profile. Any kind of interested person is welcome to join us. (Interview 11)

3.2 Role of communication in citizen participation practices in science

In this section, we present and discuss all the answers that interviewees gave us about the role of communication in their participatory activity. We have grouped them in two categories: dissemination and strengthening of relationships with stakeholders (Table 5).

Table 5. Qualitative results of the communication role in citizen participation practices in science, analysed through a categorisation system.

Communication role	*Description*	*Frequency*
Dissemination	References to communication as a tool for dissemination purposes: results, conclusions, processes or the project itself.	12/16
Strengthening of relationships with stakeholders	References to communication as a tool to establish or maintain relationships or engagement among participating stakeholders.	6/16

3.2.1 Dissemination

On 12 occasions during the 16 interviews, we found references to communication as a tool for dissemination purposes. For example, one interviewee explained to us that their communication strategy "is basically focussed on communicating what we are doing, what we have achieved, to disseminate and improve the knowledge of citizens and participants" (e.g. Interview 1).

Some interviewees mentioned publishing "results" (e.g. Interview 4), "conclusions" (e.g. Interview 2) or "the entire process of the project" (e.g. Interview 7) on the project or institution's website. There were also mentions of the dissemination of project results, conclusions or processes through social media networks in general (e.g. Interviews 4, 5, 12), or specific mentions of the network used, such as Twitter (e.g. Interviews 1, 6), Facebook (e.g. Interview 1), YouTube (e.g. Interview 2), online blogs (e.g. Interviews 1, 4) or Instagram (e.g. Interview 14).

Several coordinators mentioned using "press releases" (e.g. Interviews 7, 8, 11, 14) to disseminate their project to a wider audience; other interviewees mentioned that the project had appeared in the media with the same intention. For example, there were mentions of "press impacts" (e.g. Interview 7), appearing in "newspaper reports" (e.g. Interviews 4, 7), in "TV news" (e.g. Interviews 7, 14) or in "magazines" (e.g. Interview 4). Six interviewed coordinators also made reference to specific project outputs such as "reports" (e.g. Interviews 1, 2, 4, 6), "policy briefs" (e.g. Interview 13) or "videos" (e.g. Interviews 2, 6) published in open access and used for dissemination purposes. One of them even mentioned filming a documentary of the entire project:

> A documentary was filmed throughout the project. In this documentary, there were three protagonists and we were the theme. In other words, the sequences focused on explaining our work to achieve the objective of the project. (Interview 7)

During the interviews, we also noted mentions of the organisation of "events" (e.g. Interviews 2, 7, 10, 11), "conferences" (e.g. Interview 2, 13), "workshops" (e.g. Interviews 4, 13) or "talks" (e.g. Interview 6) to disseminate the project or its results.

3.2.2 Strengthening of relationships with stakeholders

Five of the interviewees referred to communication as a key tool for connecting with the stakeholders involved in the practice. Some of them mentioned using communication to "maintain participants' engagement" (e.g. Interview 12) during the course of the project, to provide "participation feedback" (e.g. Interview 1, 2, 11) or to "motivate volunteers" (e.g. Interview 7) to join or continue with the project:

> I was responsible for keeping volunteers informed at a particular level, that of research results, which could not be published, but which were important for them to know to maintain that motivation. I was constantly in touch with them, at their entire disposal for any difficulties that might arise, to avoid, as far as possible, that no one left the project and that the volunteers stayed on board with the operation as long as possible. (Interview 7)

It is interesting to highlight that some interviewees specifically mention that results or conclusions were "discussed" (e.g. Interview 6), "commented on" (e.g. Interview 6), "interpreted" (e.g. Interview 6) or "validated" (e.g. Interview 2) during specific meetings with participants:

> We have also written a report, which we publish in open access on our website. We have also organised a series of talks. For example, the next one will be in October. And with the participants there, we will discuss the results, we will interpret them together. (Interview 6)

Despite their differences, all the references in this category cite communication as a necessity to the effective performance of the project.

3.3 Key requirements for citizen participation practices in science

This section contains the results regarding the degree of integration of the stated key requirements for citizen participation into the 16 selected participatory practices. Table 6 offers an overview of the interview analysis. Throughout the interviews, we identified a fifth requirement, the training of participants and facilitators, which was not covered in the original protocol.

Table 6. Qualitative results of the degree of integration of the different key requirements for citizen participation practices in science, analysed through a categorisation system.

Key requirement	*Description*	*Frequency*
Derived outputs	Contributions to the science and technology system as part of the outputs of the citizen participation activity, such as scientific publications, policies, plans, or suggestions to improve the project itself.	13/16
Levels of participant's contributions	Different degrees of stakeholders' active participation during the practice, such as data collection, opinion collection or decision-making.	11/16
Participation assessment	Evaluation of the participation through, for example, interviews, surveys or analysis of the final product. It also includes data validation mechanisms of participants' contributions.	11/16
Training of participants and/or facilitators	Training of participants and facilitators as a prerequisite to the ability to carry out the practice correctly.	9/16
Replication of the practice	Replication of all or part of the practice in other contexts, countries or cities.	9/16

3.3.1 Derived outputs

Of all the interviewees, 12 mentioned contributions to the science and technology system as part of the outputs of the citizen participation activity, such as scientific publications, policies, plans or suggestions to improve the project. For example, some of them specifically referred to "scientific impact" (e.g. Interview 1), "scientific publications" (e.g. Interviews 8, 15), "publication of papers" in scientific journals (e.g. Interviews 1, 2, 6, 11, 13), publication of "scientific reports" (e.g. Interviews 1, 7) or communications at "scientific conferences" (e.g. Interviews 10, 11, 14):

> Our project has had a scientific impact. At least three new records in Spain and three scientific articles, authored by project coordinators and citizens, have been published. (Interview 1)

On the other hand, one interviewee considered that scientific publication was not in line with the primary aims of the participatory activity:

> Of course, we always publish or disseminate the results on the most open platforms possible. But we would never consider writing a paper to a scientific journal like *Science* or *Nature* because it goes against the culture we want to transmit. (Interview 4)

There were also mentions of other contributions beyond the scientific community. Some of the coordinators interviewed referred to contributions to public policies in general:

> Citizen science, as well as providing useful data for research, may also have an influence on public policy, influence decision-making, and so on. (Interview 16)

However, we also found references to specific measures from the practice. For example, "concrete recommendations for European legislation" (e.g. Interview 2), "technical reports" for the European Commission (e.g. Interview 8), or local governments (e.g. Interview 13), "a report with management guidelines for public administration" (e.g. Interview 6, 12), or use of the information collected through the practice to carry out specific actions:

> The results of the project have transcended an urban project in our city: the transformation of a large boulevard, with four car lanes, into an area dedicated to pedestrians, bicycles, with restricted movement of cars. Keep in mind that this is a critical site, an urban axis, and, in principle, the decision could have generated a lot of controversy. (Interview 7)
>
> The data we collect allows us to be aware of the situation and be able to trigger civil protection protocols if necessary. (Interview 11)

Two interviewees even mentioned that the data collected in these participatory practices led them to somewhat modify the project itself:

> We realised that the participants are much more interested in the use of these data for monitoring and control purposes than for science. So we decided to involve the public sector, which is responsible for monitoring and controlling the species in cities and towns, to use this data in monitoring and control programmes. (Interview 1)
>
> During the process, we discovered errors in our own software, which had been exploited by some participants, including some who only got involved to get the grant and weren't interested in taking part in the citizen science project. But it helped us to improve our software and helped us better understand what may motivate some people to take part. (Interview 8)

3.3.2 Levels of participant contributions

In this category, we include all mentions to the different degrees of participation identified throughout the interviews. Six out of the 16 coordinators interviewed

mentioned data collection as the primary contribution of the participants in the project. The way in which data is acquired differs depending on the activity, for example, "sending pictures and exact locations through an app" (e.g. Interview 1), or installing and using a specific device to acquire and send data (e.g. Interviews 7, 10, 11). Beyond this, one interviewee referred to data interpretation as the principal contribution of participants:

> Participants receive a series of images and have to look at them, interpret what each of the elements that appear in them are, label them and send them to us. (Interview 8)

There were two mentions of stakeholder participation throughout the entire project:

> We and the different social actors conduct the research together. Not only do they take part in the data collection, they are there from the first moment the problem is studied, the question is defined, etc., until the end, with co-decision at every moment. (Interview 13)

Two interviewees referred to the collection of participants' opinions on a specific topic as the primary objective of their practice. One coordinator mentioned "to capture the main perceptions of a small group of citizens and relevant stakeholders" (e.g. Interview 2) and "to create a list of needs and values behind each of the applications we discussed during the process" (e.g. Interview 2), while another mentioned "collecting signatures" (e.g. Interview 12) as a means of opinion collection.

Another two interviewees mentioned using opinion collection to identify research objectives (e.g. Interview 6, 9) or determine research design (e.g. Interview 9).

> What we do is go to a specific community and decide with them what to investigate in relation to their context and their group concerns. We use game theory to make an intervention in the public space, which allows us to collect this information. (Interview 6)

A total of 4 out of 16 interviewees mentioned participation in decision-making throughout the practice. For example, there were mentions of using "collaborative methodologies for co-creation" (e.g. Interview 4) during the project, working in groups "to decide on the research objectives" (e.g. Interview 13), "to discuss the best idea" (e.g. Interview 10), or even "vote for the elements to be included in the proposal at a popular assembly" (e.g. Interview 12).

3.3.3 Participation assessment

Only 8 interviewees responded that they were evaluating the participation practice. Some referred to "surveys" (e.g. Interviews 4, 12, 13), "interviews" (e.g. Interview 16) "analysing the final product" (e.g. Interview 10) or "qualitative assessment" (e.g. Interview 10) as examples of such evaluation. However, other interviewees mentioned assessment of the level of "satisfaction" (e.g. Interviews 8, 14) as the only evaluation process of the activity carried out:

> We have carried out non-formal, non-scientific surveys, but simply to analyse the degree of satisfaction with the activity. And, in general, the teachers and the children have been quite satisfied. (Interview 8)

There were also mentions of no evaluation at all (e.g. Interview 6) and comments regarding the need to improve or systematise the evaluation of the participation and the activity itself (e.g. Interview 4):

> We should try to improve the evaluation, do it every year to make it a little more systematic, precisely to be able to compare results from previous years and see the successes, the mistakes and the changes made. (Interview 4)

Five interviewees referred to the need to supervise participants' data (e.g. Interviews 1, 3, 10, 11) or interpretations (e.g. Interview 8) as a quality control before using them in the research process:

> The photographs that citizens send us are reviewed by experts, to ensure that they are the correct species. (Interview 1)
>
> If we detect an out-of-range value, we contact the collaborator to correct this. Most likely it is a machine calibration problem. If it is not possible to contact or correct it, we label it as invalid data in the database. After performing a monthly quality control, we compare data labelled as invalid with data from the same geographical area. (Interview 11)

3.3.4 Training of participants and facilitators

In 9 of the 16 interviews, when asked the question, "What did the participants have to do?", the coordinators spontaneously mentioned training as a prerequisite to the ability to carry out the practice correctly, referring mainly to the training of participants in a specific aspect. For example, interviewees mentioned "a preliminary two-day practical seminar" (e.g. Interview 4), "very intense training" (e.g. Interview 7), and "a training guide" (e.g. Interview 10) for participants. Six of these mentions come from coordinators of activities in which participants were involved in data collection. Some interviewees mentioned a train-the-trainer approach (e.g. Interviews 1, 2, 10), or the need to "develop a training unit for schools" (e.g. Interview 7) to achieve the objectives of the practice:

> Because we work with the educational sector, we train teachers so that students can also collect data and draw conclusions from the state of the municipality. (Interview 1)
>
> We teach a group of students how the app and the device work, then these students are able to teach their classmates how to do it. (Interview 10)

Other interviewees specifically mentioned the importance of training experts and organisers. For example, we found mentions to the need to "provide scientists with training on how citizen science works" (e.g. Interview 8) or to "provide us, the organisers, with training in democratic participation in science" (e.g. Interview 12).

> The initial training that the organisers received was very important. Our activity is part of an European project, and some of the partners are experts in this type of methodology, so they gave us a seminar to learn how to stimulate discussion and encourage participants to speak, and how to extract the information they provide. (Interview 2)

3.3.5 Replication of the practice

Nine interviewees mentioned that their practice, or part of it, has been or could be replicated in other contexts, countries or cities. For example, some interviewees mentioned interest from "other research groups" (e.g. Interview 1), "other researchers" (e.g. Interview 16) or "other museums" (e.g. Interview 14) to implement the same or a similar project in other countries. Other interviewees mentioned knowing that the methodology used in their practice "has been replicated in other Spanish locations" (e.g. Interview 4, 7) or "internationally" (e.g. Interview 4), sometimes with "different objectives" (e.g. Interview 7, 10):

> At first it was a super local, single-city project, then we got more funding and replicated the method in other cities nationwide. Now we are setting up a consortium and the idea is to go to the international level, try to find financing for a European project. (Interview 16)

Throughout the interviews there were also some references to "methodological publications" (e.g. Interview 1, 13), sharing methodology and experiences in "conferences" (e.g. Interview 4) or the use of "professional networks" (e.g. Interview 11) to promote replication:

> We have proposed a new methodology to improve understanding of what could be a fairer and more equitable community care model. This is the principal innovation we offer that may be useful for other groups, research fields or entities. (Interview 6)

Discussion

To the best of the authors' knowledge, this is the first exploratory study analysing citizen participation practices to have been conducted in Spain. The study offers insights into the reality of citizen participation practices in science in Spain, a country very active in scientific research and currently promoting the inclusion of society in the research process. According to our knowledge, there is no particularity of the Spanish context that suggests that the results are not valid for other countries. However, given that this is a qualitative and exploratory study, our findings cannot be considered representative of all Spanish citizen participation practices.

4.1 Stakeholders involved in citizen participation practices in science

Most of the interviewees mention a series of audiences or stakeholders identified according to the project's objectives. Different objectives mean different audiences [Kullenberg and Kasperowski, 2016], and different social actors may be involved to a greater or lesser degree in the different phases of the project [Chilvers, 2013].

As reported in the results section, the main stakeholders of several of the practices analysed were students or the educational community. Since many participatory projects also have an associated educational aim [Árnason, 2013], the participation of the educational community may seem appropriate. This public is generally associated with projects in which large-scale data collection is key to participation and large numbers of people are needed. By involving stakeholders from the educational community, large numbers of participants can be recruited for the project with only a moderate recruitment effort.

However, we must not forget that the members of this group are often a captive public [Fayard, 1987; Mitchell et al., 2017], since participation is usually decided by teachers or schools and is linked to the teaching programme. Thus, the students themselves do not volunteer to take part. Nonetheless, if we consider that a fully developed citizenship should incorporate science literacy and scientific practice, including the educational community in participatory science projects could foster scientific modes of reasoning among future generations of citizens [Strasser et al., 2019] and scientists [Mitchell et al., 2017].

A study on the implementation of citizen participation projects in science in Catalonia (Spain) reports that students would like to continue taking part in such projects, but preferably mainly at school, rather than individually or with family members [RecerCaixa, 2016]. Further study will be necessary to determine whether the fact of taking part in participatory science activities during their school years influences citizens' willingness to take part in such democratic activities in the future. Mitchell et al. [2017] who included a citizen science assignment in a large undergraduate biology class, found a significant increase in environmental engagement and the majority of the students planned to continue to contribute to that programme.

Although most of the interviewees mentioned the selection of strategic publics, in some interviews the coordinators still viewed the public involved in their projects as a single entity. Greater experience in public engagement activities is associated with greater understanding of multiple publics [Besley and Nisbet, 2013]. The inclusion of multiple publics in participatory science activities promotes the analysis of problems from different perspectives and the search for joint solutions for a shared future [Jacobi et al., 2017; Malyska, Bolla and Twardowski, 2016; Welp et al., 2006], raises research questions and previously uncontemplated lines of research [Frickel et al., 2010], and increases the legitimacy of science governance [Bernauer and Gampfer, 2013].

Previous works have revealed that younger generations of scientists tend to receive more specialised training in such activities [Llorente, Revuelta, Carrió and Porta, 2019]. Our hypothesis is that including more formal training for scientists in science and society relations could foster a more realistic view of the public and help to boost citizen participation projects in science.

4.2 Role of communication in citizen participation practices in science

Communication plays a key role in participatory projects. It is essential for project dissemination, results, conclusions and derived outputs as well as for participant

recruitment. It is also necessary for maintaining and strengthening stakeholder-coordinator relationships.

Therefore, a participatory science process needs to be understood as a two-way commitment that requires a continuous two-way communication [Trench, 2006]. By participating, citizens accept a commitment to the research team; at the same time, the research team makes a commitment to the participants. This means that there should be no participation without return, either in the form of shared knowledge, recognition in derived products, or specific actions linked to the objectives of the project itself, beyond the scientific objective [Kullenberg and Kasperowski, 2016]. Communication is an essential tool to enable this to take place.

Although communication, public engagement and collaborative strategies are fundamental elements in the professional life of scientists with significant social implications, most Spanish universities do not include training in these skills in science degrees [Revuelta, 2018]. Therefore, greater efforts for better training for future scientists regarding communication skills and how to establish such relationships are needed to efficiently implement the deliberation model of communication [Horst and Michael, 2011].

4.3 Degree of integration of key requirements

This study analyses the degree of integration of the four key requirements for developing citizen participation in science practice: derived outputs, level of participant contribution, participation assessment, and practice replicability. Following analysis of the interviews, we added a fifth requirement: training of participants and facilitators.

The derived outputs of such practices are very different (scientific publications, policies, plans, concrete actions, etc.) and will depend, above all, on the specific objectives of each project. Citizen participation in science activity must make some kind of contribution to the science and technology system. The participation of citizens must respond to a specific objective and result in the co-production of some type of output. Otherwise, participation cannot be considered an element of democratic citizenship [Baum, 2015] or a matter of cognitive justice [Irwin, 2001], nor would it be responding to the social demand for a more active role in these processes [Rogers, 2006].

As we have seen, citizens can participate in science along a spectrum from collecting data to co-construction of knowledge and research through deliberative approaches [Schrögel and Kolleck, 2019]. Thus, the common element in this broad range of participation is that the citizen plays an active role during the process. However, the current literature suggests that a large part of the scientific community continues to consider the deficit model the best way to approach the public [Jensen and Holliman, 2016; Metcalfe, 2019; Seethaler et al., 2019; Simis et al., 2016]. This approach implies a passive audience and a perception of the capacities of the public incompatible with a participatory, co-production approach.

Even so, researchers more active in public engagement activities have a better understanding of the public and their ability to take part in knowledge

co-production processes [Besley and Nisbet, 2013]. Previous studies have revealed that Spanish scientists consider public engagement activities a shared responsibility among institutional communication departments, journalists and researchers [Llorente, Revuelta, Carrió and Porta, 2019]. This conceptualisation of public engagement as a multidisciplinary activity involving collaboration among different actors is also consistent with the participatory approaches analysed here.

In general, there is a lack of assessment, with confusion between evaluation of the participatory activity itself and evaluation of participant satisfaction. Although the evaluation of citizen participation in science has evolved in recent years, there is a lack of consistent evaluation criteria for systematic and transparent assessments of success and failure [Haenssgen, 2019].

We consider that the evaluation of the participatory activity should be conceptualised from the beginning of the project, since it is the only way to verify whether the participatory process is meeting the stated objectives as well as citizen participation in science good practice standards [Haenssgen, 2019; Jensen and Holliman, 2016]. This type of evaluation may exceed the competences of the research staff. However, most practices that include data collection or interpretation have established mechanisms for validating the contributions of non-scientists to the project.

As discussed in previous sections, many of these participatory practices also include an objective related to learning or the acquisition of new knowledge or tools. It should not surprise us, then, to find that training is a key element of citizen participation in science. However, there are two types of training to carry out an efficient citizen participation practice.

Depending on the level of participation, there will be a need to train the stakeholders involved (to acquire common basic knowledge for data interpretation, use of specific software or tools, etc.) to enable them to take part. Meanwhile, training the members of the research staff in participatory strategies and public understanding of science will be equally important and necessary. Moreover, if we take into account the multiple objectives of participatory projects it is also key to design the learning process to be able to assess it [Pandya and Dibner, 2018].

As for all types of scientific production, the participatory methodologies used in citizen participation processes should be able to be replicated in other contexts, countries or cities. In the results reported in the previous section, we can see that this is an element that is usually taken into account in this type of project. Notwithstanding, replicability should be considered from conceptualisation of the project.

Conclusions

In view of the potential benefits for science and technology processes associated with citizen participation, there is a need to understand the nature of the practices currently being carried out. In this article, we have addressed the Spanish context through a qualitative approach with the aim of providing an exploratory view of citizen participation in science. As such, our conclusions should not be over interpreted. Further research is needed to fully understand Spanish citizen

participation in science and our suggestions should not be taken as definitive, but rather as the focus for potential strategies to foster science-society relationships.

We analysed the degree of integration of what we consider the five requirements for the development of a citizen participation in science practice: derived outputs, level of participant contribution, participation assessment, replication of the practice, and training of participants and facilitators. Such requirements need to be addressed before starting the participatory process in order to allocate the necessary resources, both human and economic, to cover extra duties beyond the researchers' routine tasks.

Depending on the degree and type of involvement expected of the participants, it will be necessary to include training prior to commencement of the practice. Equally important is to anticipate the collaborative methodologies training needs of the research team. There is also a need to train facilitators of participatory science activities with respect to the importance of these processes and the methodologies needed to assess these processes. Otherwise, it will be impossible to verify whether the participatory process is meeting the stated objectives as well as good practice standards for citizen participation in science.

In participatory practices, extra effort must be invested during the conceptualisation phase to identify the potential stakeholders, the most appropriate recruitment and engagement strategies, and the expected level of commitment to the project. For this to be carried out successfully, training on how to establish collaborative relationships will be necessary.

Communication has been revealed as a key tool for the successful development of citizen participation practices in science, both for dissemination and for strengthening relationships with stakeholders. We believe that, in addition to the training already discussed, there is a need for multidisciplinary teams with solid knowledge of the scientific and technical elements to perform the project, as well as the skills required to enact communication, public engagement, co-production and deliberation strategies.

Until citizen participation in science becomes a reality, the existing barriers — such as lack of time, resources, recognition and training — must be taken into account and efforts made to promote solutions. The main contribution of this study consists of the strategies proposed to reduce those barriers.

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