Analysis of citizen participation in science: perceptions of the different actors involved

Carolina Llorente Lope

DOCTORAL THESIS UPF / 2020

Thesis supervisors

Dra. Gema Revuelta

Dra. Mar Carrió

DEPARTMENT OF EXPERIMENTAL AND HEALTH SCIENCES

Universitat Pompeu Fabra Barcelona

Agradecimientos

Esta tesis no habría sido posible sin mis dos tutoras la Dra. Gema Revuelta y la Dra. Mar Carrió quienes me han descubierto un ámbito de investigación que encaja con casi todas mis inquietudes. Gema, muchísimas gracias por ofrecerme hacer esta tesis, darme la oportunidad de trabajar en el CCS y con ello tantas oportunidades profesionales que no caben en un único párrafo. Mar, moltes gràcies per acceptar de seguida ser tutora d'una tesi que se surt una mica del teu àmbit de recerca, pels consells, les revisions i tots els ànims durant aquests anys. Al final, crec que totes hem gaudit d'aquesta recerca.

Estos años en la UPF han servido para ponerme a prueba constantemente, aprender muchísimo y ganar confianza en mis capacidades. Sin embargo, de una de las cosas que más me alegro es de haber conocido a tanta gente buena, lista y capaz que forman (o han formado) parte de nuestro grupo a quienes, por supuesto, tengo que dar las gracias por todo su apoyo tanto laboral como personal. A Luisa, mi todera favorita. ¡Ya no sé qué sería de mi vida sin una compañera tan válida, resolutiva y positiva a mi lado! A la Júlia, que sempre afronta els reptes amb un somriure. Gracias a ambas por echarme una mano con cualquier cosa cuando estaba en uno de mis "días de tesis" y, sobre todo, por hacer de la oficina un lugar más "chévere". Per descomptat, gràcies també a totes les companyes i companys del GRECS amb els que hem compartit espais, cafès, dinars, pinxos, reflexions i alegries durant aquests anys pre-doctorals.

No puc oblidar-me de la Gemma, l'eterna companya de despatx i d'aventures i desventures doctorals. Gràcies per compartir tots els teus coneixements d'anàlisi qualitatiu amb mi, per resoldre'm mil i un dubtes sobre el procés de dipòsit de la tesi i, encara més, per fer-me un lloc a la teva vida. Ni tampoc de l'Amèlia i la Carol que aconsegueixen convertir en una festa qualsevol trobada, per molt desesperada que estigui amb resultats que se'm resisteixen. Gràcies a les tres pel temps que hem compartit al PRBB i pel grup tan maco que hem arribat a formar. Tot i les nostres agendes complicades, espero molts més sopars, festes, confidències i seguir creixent al vostre costat.

Si alguien merece aparecer en los agradecimientos de mi tesis es, sin duda, mi familia. Gracias por estar ahí siempre. A Silvia, mi madre y ahora también compañera de trabajo. La primera persona que me animó cuando la idea loca de trabajar y hacer la tesis al mismo tiempo se me cruzó por la cabeza y quien siempre tiene tiempo para escucharme, ayudarme y repasar análisis de resultados: gracias por todo. A mi padre, Gustavo, por sus consejos, ánimos, apoyo, comprensión, lecturas y relecturas… y todos los banquetes deliciosos (pre y post-COVID) que han acompañado la escritura de esta tesis. Gracias por creer en mí y enseñarme a celebrarlo todo. A Alicia, mi hermana, que sabe mejor que nadie lo duro que es escribir la tesis en tiempos de confinamiento. Gracias por todo tu apoyo moral y emocional estos meses. Te prometo que después de todo haremos nuestro viaje, será tarde, pero como (casi) Dras. Llorente. ¡Qué suerte tener esta familia!

David, nunca tendré espacio ni tiempo suficiente para agradecerte toda la confianza que tienes en mí. Porque crees que puedo conseguir absolutamente todo lo que me proponga y que no hay límites si pongo el empeño suficiente. Gracias por tu paciencia, tu apoyo, tu comprensión, tus ánimos constantes, por leerme, releerme y escucharme reflexionar en voz alta, por estar siempre, por quererme y por cuidarme tanto. Gracias por enseñarme a mantener la calma, a relativizar y a afrontar las cosas poco a poco. 2020 no se nos va a olvidar nunca, por la pandemia, pero también por nuestros éxitos.

Gràcies Andrea, Eloi, Laia i Laura: per ser els amics amb els que pots comptar, per tenir sempre un moment per escoltar-me, per ser els millors *coach* emocionals i, sobre tot, per voler compartir les alegries i tristeses de tots els moments que la vida ens posa per davant. Laia, mil milions de gràcies per les revisions de l'anglès t'hauré de convidar a birres d'aquí fins l'eternitat per poder compensar-te. Eloi, gràcies pels teus consells de professional en l'etapa de maquetació de la tesi. Andrea, gràcies per les trucades setmanals, per fer-te sentir tan a prop vivint tant lluny i compartir amb mi la saviesa que et dona ser la primera doctora del grup. Laura, gràcies per treure temps i ganes de la bogeria del MIR i del treball assistencial a l'hospital per acompanyar-me emocionalment en aquest procés. Tenim pendent una celebració.

Y gracias a tantos otros que siempre están acompañándome en los momentos importantes. La familia de Can Formiga que nunca falla y con los que siempre se celebran las cosas por todo lo alto. Espero que me invitéis pronto a una buena comida en el jardín de la casa de Aiguafreda para celebrar un doctorado más del clan. Els amics de Biologia pels que la distància mai és massa per deixar de preocupar-nos els uns pels altres. Ara ja tinc una excusa per no esperar fins al, ja

tradicional, sopar de Nadal per tornar-vos a reunir a tots sota un mateix sostre. Aneu esperant l'Excel. Els amics del Màster amb els que seguim quedant, parlant i arreglant el món des del 2013 i que esperen des de fa temps la lectura de la meva tesi. A la propera quedada toquen copes de celebració. Y mis, ahora sí, amigos de Hospitalet que me acogieron como a una más del grupo, me integraron en su barrio y que siempre se alegran de mis éxitos. No cerraré el Depo para celebrarlo, pero ya tenemos otro motivo para brindar este 2020.

A todos vosotros, gracias por haber formado parte de esta aventura.

Abstract

The main objective of this thesis is to improve understanding of citizen participation in science in Spain. Specifically, it analyses the characteristics of current participatory practices and the opinions and attitudes of two of the main actors involved (scientists and citizens). The research has been divided into three studies based on qualitative (semi-structured interviews) and quantitative (questionnaires) methodologies. The main results suggest that activities of citizen participation in science require solid scientific communication throughout the process, as well as prior planning and training (for participants and for researchers). The results indicate that Spanish researchers do not fully know their publics. However, scientists consider that they have a responsibility in science communication and public engagement activities. Spanish civil society organizations participate to a less extent in science and do not know their own potential to produce more socially relevant research.

Resumen

Esta tesis tiene como objetivo principal mejorar la comprensión sobre la participación ciudadana en ciencia en España. En concreto, analiza las características de prácticas participativas actuales y las opiniones y actitudes de dos de los principales actores involucrados (científicos y ciudadanos). La investigación se ha dividido en tres estudios basados en metodologías cualitativas (entrevistas semiestructuradas) y cuantitativas (cuestionarios). Los principales resultados sugieren que las actividades de ciencia participativa necesitan una buena comunicación científica a lo largo de todo el proceso, así como planificación y formación previas (para los participantes y para los investigadores). Los resultados indican que los investigadores españoles no conocen del todo a su público. Sin embargo, consideran que tienen una responsabilidad en la comunicación de la ciencia y las actividades de *public engagement*. Las organizaciones de la sociedad civil española participan poco en ciencia y no conocen su propio potencial para producir una investigación socialmente más relevante.

Preface

There is a global trend for a broader, more inclusive and open science where citizens play an active role in research, innovation and governance. This new approach of science production implies a structural change in the science and technology system as well as a change in the science-society relationships. In this context, there is a need for more research to better understand this situation and scientists' and citizens' perceptions and limitations in order to propose effective solutions to foster citizen participation in science.

This thesis analyses citizen participation in science in Spain, a country very active in scientific research that is recently promoting society inclusion in this process. The investigation of this thesis is organized in three studies that have contributed to better understanding the current situation by analysing for the first time in Spain three key aspects: 1) Current participation practices in science, 2) Scientists' perceptions of Spanish society and 3) Civil society organizations' managers' perceptions of participating in science.

This research has revealed aspects of citizen participation in science that were unknown until now. Among others, the study identified training needs (both for citizens and for investigators or coordinators of participatory activities) and the need for better science communication at different levels (and with different objectives) throughout the entire research process.

We have also detected important differences between the perceptions of Spanish scientists about the public and what is included in official reports of public perception of science in Spain. Specifically, these differences relate to the sources of information used by the public, the level of public recognition that science and researchers receive, the level of scientific education and the level of interest in science and technology.

The findings also suggest that civil society organizations are unaware of their own knowledge and potential in producing a more socially relevant science. There is a need to solve the divergence of objectives, research continuity and lack of communication between civil society organizations and the academia to foster citizen participation in the science and technology system.

The research carried out during this thesis have contributed to better understanding citizen-science relationships in Spain. Therefore, the new knowledge generated with this thesis can be taken into account to propose strategies to foster citizen participation in science. To face the challenges detected and better understand the situation, the author of this thesis proposes future research lines.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

"Never doubt that a small group of thinking and committed citizens can change the world. In fact, they are the only ones who have succeeded".

Margaret Mead
Anthropologist

1.1 Interest of the topic

Citizen participation in socially relevant issues is something that humanity has been seen throughout its history. Democracy is one of the clearest examples in which the participation of citizens in their own governance is revealed.

However, how this participation is carried out, the level of involvement of citizens and even who can participate in these processes varies among time and different societies. The rise of the Internet has increased the organization and participation of our societies. Therefore, modern society has a huge potential to exert social pressure and thus put specific issues on the political agenda.

Throughout history, we can see clear examples of how, in addition to the political agenda, society can influence the course of scientific research in different topics. For example, the strong social movements of women activists regarding breast cancer therapies in the 1970s, of AIDS patients in the 1980s or the movement against climate change led by Greta Thunberg in 2010's. The recent COVID19 pandemic has put in the spotlight scientific research as a source of evidence for decision making in daily lives more than ever.

In the last decades, various philosophical-political movements have emerged seeking for a more inclusive and participatory production and governance of science (e.g., responsible research and innovation, quadruple helix model of innovation or open science). The main goal of those movements is to carry out a more democratic science aligned with the objectives, needs and expectations of society. Political institutions, both international and local, are promoting this new approach of scientific production.

Nevertheless, this implies a structural change in the science and technology system as well as a change in the mentality and science-society relationships during the research process. Under these circumstances, there is a need for more research to better understand the situation and the different actors' perceptions and limitations in order to propose effective solutions to foster citizen participation in science.

This thesis therefore seeks to analyse this issue in Spain, a country very active in scientific research that is recently promoting the inclusion of the society. Concretely, it assesses current participatory practices in Spain and the perceptions of the main actors involved, scientists and civil society.

1.2 State of the art

The main purpose of this section is to explain the background and relevance of the framework of this thesis. It starts with an overview of the current socio-political movements that frame citizen participation in democracy and governance. Followed by the state of the art in citizen participation in science and its current approaches, potential benefits and challenges. Subsequently, there is an analysis of the main actors involved and their roles in such participatory processes. It finishes with a brief overview of the Spanish context is included.

1.2.1 Democracy, governance and citizen participation

Citizen participation is a key element of democratic cultures, as without participation there is no real democracy. However, who we consider citizens, who can participate, and how they participate in political and governance decision-making, are elements that have substantially changed throughout history.

Movements that promote an increasingly active role for citizens in democracy, such as participatory democracy, deliberative democracy or participatory culture, have sprouted up in the last two centuries. Below, a brief overview or each movement is presented.

a) Participatory democracy

The concept of participatory democracy emerged in the United States in the 1960s. This conception of democracy was focused on the potential of self-development and the rejection of the idea that individuals are inherently incapable and incompetent of making socially effective decisions (Dahl 2005; Hilmer 2010).

This vision of participation specifically refers to equal participation in the decision making, and "political equality" refers to equality of power in determining the outcome of decisions (Pateman 1970). Its mechanism can be defined more precisely as a political model that facilitates citizens' ability to associate and organize in a way that they can directly influence public decisions.

What is important in this vision is to make decisions in conditions of equality but how to transform these decisions into a political reality was left unspecified. This has been highlighted as the main weakness of this tradition (Mansbridge 1983), and it contributed to the gradual decline in interest for its underlying political approach during two decades.

In the late 1990s and early 2000s, the concept of participatory democracy reappeared strongly following the local views of democracy against the prevailing trend of globalization. At this time, this concept includes all forms of democratic participation (e.g., popular consultations, citizen referendums, participatory budgeting, neighbourhood or community councils etc.) directly involving citizens in the policy making processes (Hilmer 2010). This contributed to the association of citizen participation in democratic processes as a form of empowerment.

However, citizen participation in democracy requires acknowledgment of the exercise of power on the one hand, and active education in citizenship on the other (Smith 2009). Thus, participatory democracy is mainly focused on promoting new relations with citizens and is increasingly seen as a way to contain and widespread deficit of consensus and loss of effective mediation between civil society and political institutions (Hilmer 2010).

b) Deliberative democracy

In the first half of the 1980s Joseph M. Bessette (1980) coined the term "deliberative democracy" which was supported by some constitutionalist scholars and philosophers of law (Bohman and Rehg 1997; Manin 1987). From then until now deliberative democracy has become an umbrella expression for various approaches, which still share the following assumptions (Bächtiger et al. 2018; Visser 2018):

1) What matters in democracy is constructing collective decisions through public dialogue and shared argument.
2) The importance of deliberation consists in increasing the epistemic and cognitive base for decision making and the legitimacy of political decisions.

This vision requires creating arenas of discussion that possess the characteristics for promoting efficient and legitimate deliberation among different stakeholders (e.g., consensus conferences, citizen panels, citizen assemblies etc.). Experiences on deliberative democracy highlighted forms of participation and engagement based on the idea of "citizen representatives" or "mini publics" (Urbinati and Warren 2008) contributing to the formulation of policy decisions. But there are also proposals of open and inclusive deliberative arenas that complement political representation by valorising opinions, interests and forms of competence and knowledge production that cannot be handled by policy-makers or political institutions (Davies et al. 2012).

However, for this vision to be effective, active citizen participation becomes central in deliberative processes to translate its normative idea of democracy into a practical exercise of governance. Not all forms of participatory democracy are necessarily of a deliberative type but, in practice, there is a huge variety of participative processes that include a relevant deliberative dimension.

c) Participatory culture

According to Jenkins et al. (2009), participatory culture can be understood as "a culture with relatively low barriers to civic engagement, strong support for creating and sharing creations, and some type of informal mentorship where experienced participants pass along knowledge to novices". In such cultures, members believe that their contributions are relevant and feel some degree of social connection among themselves (Jenkins et al. 2009).

At the same time, the democratization of knowledge and recent surge of new technologies also opens up opportunities in the field of public participation in the form of co-creating knowledge (Stilgoe, Lock, and Wilsdon 2014). Internet has promoted the expansion of this participatory culture as well as the possibilities it offers by becoming a unique medium of participation, interaction and democratization (Porlezza 2019). However, there are different manifestations of participatory culture such as affiliations, expressions, collaborative problem solving or circulations (Jenkins et al. 2009) that don't necessarily need to take place in a virtual environment. Despite its differences, all aforementioned participatory approaches have in common an active role of citizenship in knowledge and art production or in decision making.

Probably the greatest example of participatory culture is Wikipedia and its community. This encyclopaedia is completely created by voluntary participation because it was designed to allow citizen content contribution and community participation (Xu and Li 2015). Of course, there are differences on the degree of participation among community members, but it is something inherent of any kind of citizen participation.

There are also experiences of formal citizen participation (e.g., citizen consultations, citizen representations etc.) in political decision making. For example, the citizen council of the German-speaking community of Belgium (Niessen and Reuchamps 2019), a permanent system of political participation that allow citizens decide each year on specific topics (e.g., childcare). There are similar experiences with citizen assemblies in Ireland (Farrell, Suiter, and Harris 2019) using 100 citizens for a number of important constitutional changes on topics such as gay marriage or abortion.

But also there are examples of volunteer participation in deliberative approaches involving decision making. For example, to determine local budget allocations in Barcelona (Serramia et al. 2019) or in Ukraine (Volodin 2019). And also to undertake major public projects such as the rebuilding of New Orleans after Hurricane Katrina (Weil, Rackin, and Maddox 2018), where citizens were involved in drafting and approving the plan. We can also found examples of citizen involvement in science such as patient advisory boards that help pharma companies by providing input into clinical trials designs and execution (Anderson, Benger, and Getz 2019) or citizen contributions in biodiversity conservation. Perhaps the best known example of this last citizen involvement is the amateur birdwatching contributions, a very large community with a long tradition which has increased its activity with the rise of the internet (Moss 2005).

All this supports the idea that participation in decision making processes that affects individual and collective interests is a basic element of democratic citizenship (Baum 2015). Furthermore, it is a matter of cognitive justice (Irwin 2001) and fulfils the reported will of society to acquire more responsibility in decision making (Rogers 2006). In fact, public participation in knowledge production and its governance can be considered a democratic right of modern citizenship (Liston 2019).

These structural changes in democracy, as well as the increase in participatory culture, among citizens are the ideal breeding ground for promoting citizen participation in any social construct and its governance. And this is the moment when we have to start considering science, and its production, as a construct of society. Therefore, an area that cannot be exempt from citizen participation. It thus appears that science governance and production is no exception to the broader participation imperative placed on our democracies (Godden 2017).

1.2.2 Citizen participation in science

Science as a profession, and as a social institution, has a history in which the articulation of concerns about the science-society relationship has been constant (Gregory and Lock 2008). To what extent society should perform this legitimating role has been under long-term debate (Gregory and Lock 2008). On the other hand, until recently, the scientific community has been isolated from society and still prevails the idea that non-scientific citizenship cannot contribute to the construction of scientific knowledge (Jensen and Holliman 2016; Metcalfe 2019; Seethaler et al. 2019; Simis et al. 2016).

By the end of the 20th century, "science and society" was a matter for government policy and during the past decade the involvement of non-scientists in research has engaged an increasing number of academic researchers in a new scenario of science production (Strasser et al. 2018). Greater participation of citizens in the orientation of research and/or in the production of knowledge is valued for the sake of democracy, a vision supported both in theory (Wylie 2015) and, in practice, for global strategic policy reasons (Hockfield 2018). There is a general trend towards broader, more inclusive and active participation of different social groups in science and technology, as can be seen in the greater diversity of research and coordination activities around the world (Hockfield 2018; Mejlgaard et al. 2018).

This new paradigm of scientific production involving citizens implies an epistemological change that goes beyond placing science in a broader human, social and cultural context. Citizen participation in science requires a structural change in the way of producing new scientific knowledge that affects, on the one hand, the work of scientists and, on the other, the mutual influences between science, technology and society.

However, there are still many discrepancies in how this non-scientific involvement should be done, different understandings of what participation in science is and what kind of stakeholders should be engaged in the research process. In the following subsections, the current panorama of the different socio-political movements regarding science-society relationship is presented. Secondly, a reflection on communication roles in participatory process is included. Then, we present the different categorizations of citizen participation in science. Finally, an overview of the potential benefits and main challenges of participatory approaches of science production is detailed.

a) Science-society relationships

During the last decade, some social opinions on scientific and technological issues have shaped decision making regarding scientific policies, for example, in the case of genetically modified food and the trade of genetically modified organisms (Berg and Lidskog 2018; Buiatti, Christou, and Pastore 2013). Also, strong social movements regarding antiretroviral drugs pricing in developing countries (e.g., HIV/AIDS treatment) have led to the formulation of specific laws to transform the market (Kapstein and Busby 2016).

How public attitude towards science and technology affect science-related areas of public policies can also be seen in the installation of wireless smart meters. Such meters promise numerous environmental benefits, but they have been installed without fully consideration of public acceptance which, once installed, has led to some social movements that reject this technology (Hess and Coley 2012). Another example is the phenomena of Greta Thunberg and Fridays for Future, which has prompted unprecedented numbers of young people from all over the world to join the movement against climate change (Fisher

2019). This influence is important beyond its potential impact on climate policy because it is creating a cohort of citizens who will be active participants in democracy (Fisher 2019).

Such inclusion of society in scientific processes and their governance has been formally promoted by different movements of democratization of science. Three of the main movements are described below:

i) Responsible research and innovation

Since 2010, the term "responsible research and innovation" (RRI) has gained increasing policy relevance. In particular, within the European Commissions' Science in Society program, framed within the European Union Horizon 2020 initiative. The RRI concept is based on the idea of a shared responsibility of science production and its governance.

The most referenced definition of RRI, both in literature and in European Commission speech, is probably the one coined by René Von Schomberg (2011).

> "Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)"

RRI has been also described by Stilgoe et al. (2013) as "taking care of the future through collective stewardship of science and innovation in the present". They also divided their framework in four dimensions of responsible innovation: anticipation, reflexivity, inclusion and responsiveness.

At the same time, there are institutional definitions that refers to the same concept as, for example, the proposed by the European Commission (2014):

> "Responsible Research and Innovation means that societal actors work together during the whole research and innovation process in order to better align both the process and its

outcomes, with the values, needs and expectations of European society"

The European Commission identified six key issues under RRI umbrella: ethics, gender, public engagement, governance, open access and science education. Figure 1 offers an overview of the six key issues and Stilgoe et al. (2013) four dimensions.

The beauty and complexity of this concept is that it is both a philosophical concept and a principle of research and innovation policy. Despite not having a single definition, RRI represents a movement for change of the current science and technology system and has been built upon the intersections of various movements and disciplines, some of them of long-standing tradition (e.g., ethics, research integrity, gender equality, public engagement…). But, above all, RRI seeks to achieve a more socially robust scientific knowledge, and that science production is seen by society to be both transparent and participative (Gibbons 1999).

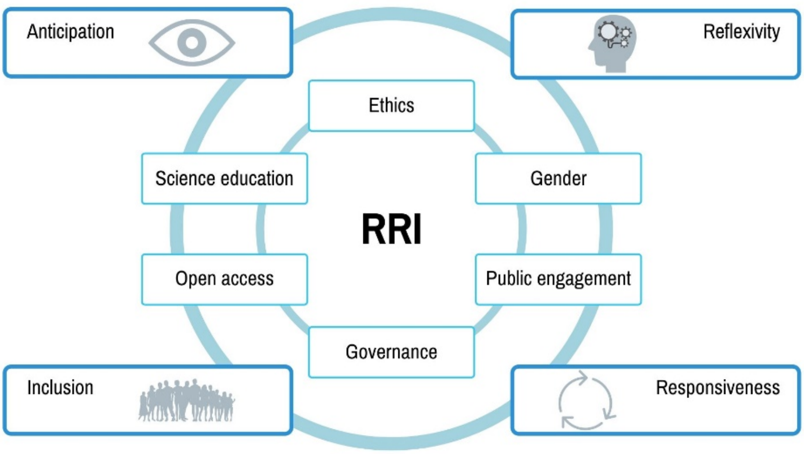


Figure 1. RRI diagram including the Stilgoe et al. (2013) four dimensions and the European Commission six key issues (2014). Source: own elaboration.

Thus, RRI can be understood as a revolutionary movement to improve science production and its governance beyond mandatory, but it also receives strong institutional support both from international (especially

European Commission) and national organizations. Those institutions support the dissemination of RRI, and its integration into professional routines, in the higher education of future scientists, engineers and other professionals involved, affected by or interested in research, development and innovation.

ii) Quadruple helix model of innovation

Our current society is divided into different sectors. According to the most widespread triple helix model, those considered to be the most relevant in innovation processes are; academia, industry and the public sector. The biggest difference between the "quadruple helix model of innovation" movement and previous conceptions is that it considers society as the forth, and main, actor in the innovation system (Carayannis and Campbell 2009).

With the inclusion of civil society, the model becomes a "quadruple helix" and the terminology changes towards "citizen-driven innovation", "co-creation" or "crowdsourcing", among others. This terminology is used because the objective of innovation becomes development and regional growth, seeking general solutions to society's problems, and not individual products independent of social needs (Lindberg, Lindgren, and Packendorff 2014).

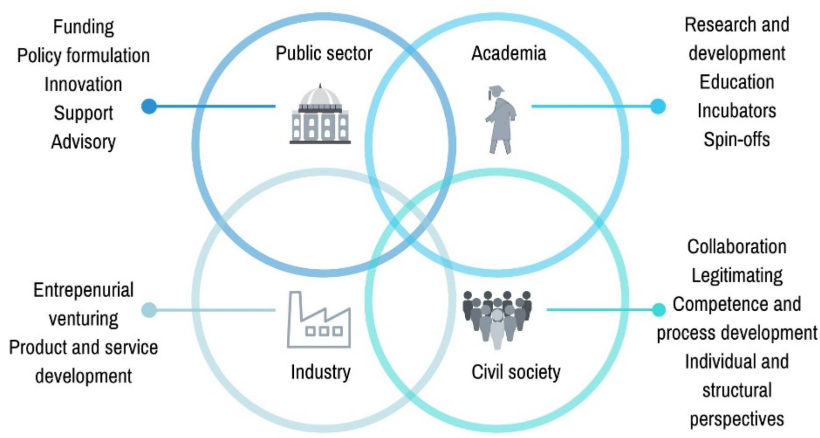


Figure 2. Quadruple helix model of innovation based on Lindberg et al. (2014) representation. Source: own elaboration.

The new model seeks to break the traditional barriers of dialogue between government, industry, academia and civil society, by bringing together its multidisciplinary views in an environment that promotes teamwork, collaboration and the exchange of ideas (Carayannis and Campbell 2009). Civil society not only uses and applies knowledge and demands innovation in the form of goods and services, but also becomes an active part of the innovation system (Schütz, Heidingsfelder, and Schraudner 2019).

iii) Open science

Open Science represents a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and new collaborative tools (European Comission 2020). Essentially, the "open science" movement covers the entire production cycle of scientific knowledge, including the conception, data collection, processing, publication and distribution, or reuse, and evaluation of results (Gallagher et al. 2019).

Gallagher et al. (2019) proposed six core principles of open science summarized in Figure 3:

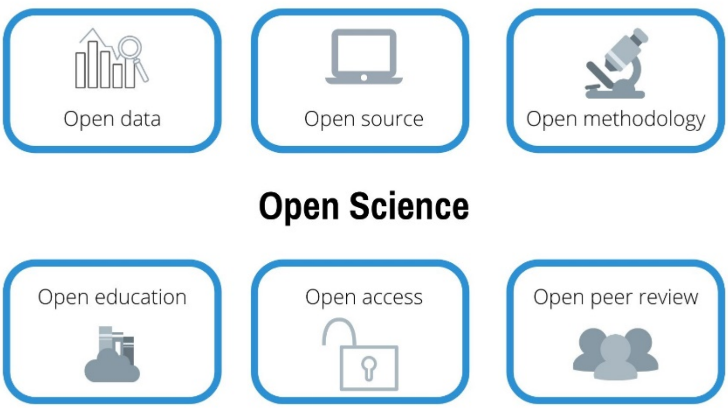


Figure 3. The six core principles of open science proposed by Gallagher et al. (2019). Source: own elaboration.

This is not a new concept, although the agreement on this term and its widespread use is relatively recent because it has been preferred by the stakeholders (European Commission 2015). Open Science seeks to extend the principles of openness to the whole research cycle, fostering sharing and collaboration of all kinds of scientific knowledge as early as possible and making scientific data and production accessible to everyone (Vicente-Saez and Martinez-Fuentes 2018; Woelfle et al. 2011).

"All kinds of scientific knowledge" means articles in scientific journals, data, code, online software tools, questions, ideas, speculations, mistakes and anything that can be considered knowledge. And "as early as possible", implies that very often there are other factors (e.g., legal, ethical, social ...) that must be considered before sharing knowledge.

One of the main arguments behind Open Science is that scientific knowledge is a product of social collaboration and its ownership belongs to the community (Fecher and Friesike 2014). But also, that scientific outputs generated by public research are a public good that everyone should be able to use at no cost (Fecher and Friesike 2014).

These three philosophical-political movements put citizens in an active role during the scientific process, whether from the conceptualization of research, during research, or in the communication of results and decisions based on evidence. What is clear is that there is a general trend in those scientific production models that implies both structural changes in the system itself and changes in the mentality and roles of the different actors involved.

b) Communications roles in science participatory processes

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 scientists to gain the trust of stakeholders 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 and therefore, a key to successful research projects (Fernández Beltrán and García Marzá 2017).

The traditional science communication is mostly unidirectional, thus to carry out such participatory processes it is necessary to add a greater degree of interaction between researchers and publics. According to Perrault (2015) and Alcíbar (2015), the unidirectionality of the "Public appreciation of science and technology" model must be overcome. In this model the flow of information goes from the scientists, that act as the active disseminator and the one who controls the meaning of "the scientific" and "the non-scientific", to the public, who is a passive deposit of information. This model is also known as a "model of cognitive deficit" or "scientific literacy" (Brossard and Lewenstein 2010).

This model coexists with others that offer a greater interaction such as the "Public engagement with science and technology" model that conceives communication as a two-way flow between science and the public and emphasizes the need to establish mechanisms that favour dialogue between science and society (Brossard and Lewenstein 2010). That's why it is also known as a "dialogue model". However, despite the bi-directionality, there are still some problems in this model as it continues to separate science and society. Even when it tries to establish a dialogue between them, 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 "Critical understanding of science in public" model 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, also known as the "deliberation model" (Horst and Michael 2011), scientific knowledge and its dissemination continue to matter, but more emphasis is placed on how that knowledge is socially used. An aspect directly linked with the aforementioned philosophical-political movements on science production and governance.

Scientific participatory processes require a continuous two-way communication, thus communication itself has become a key tool in order to establish, maintain and strengthen relationships between all actors involved (Trench 2006). Communication can even be the basis for the effective achievement of citizen participation projects based on deliberation (Ott and Knopf 2019; Roberts 2004) or those seeking citizen participation in 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 ways of understanding the science-society relationship and science communication are complementary and enrich each other. Thus, without a more informative communication it is difficult to establish a real and contextual dialogue.

In this sense, the development of participatory scientific processes requires a public communication of science and technology that takes into account both the critical training of citizens and the establishment of a dialogue between science and society throughout the research process. Thus, to successfully develop a citizen participation project is necessary to understand science production and governance as an interactive part of society and considering that both scientific, and non-scientific, forms of knowledge have value. Therefore, the deliberation model seems to be the most appropriate communication approach for such processes.

c) Levels of citizen participation in science

Science-society relationship has shifted from deficit to deliberation model (Smallman 2018). A variety of other terms have been used in current literature to designate practices that fit with the abovementioned understandings of science-society relationships including "citizen science", “public participation”, “amateur science”, “community based research” or “social participation in scientific research” (Kullenberg and Kasperowski 2016; Strasser et al. 2018). Despite the differences that may exist between these terminologies, all of them refer to participatory practices aiming at including non-scientists in the creation of scientific-technical knowledge.

According to Baum (2001) citizen participation can be understood as “citizen involvement in public decision making”. But what “citizens” or “participation” mean may differ among individuals. For example, under the label “citizens” we can include either organized communities such as civil society organizations, companies or professional associations, or just individuals. When using the term “public” or “citizen” it is important to consider that we are actually referring to “multiple publics” (Besley and Nisbet 2013): different groups of people with diverse interests and perceptions on a given topic.

Similarly, the term “participation” remains open to multiple interpretations. It may involve observation, consultation or production in science related issues either political decisions or along a research project. The main important thing is that the citizen participation concept represents remedial efforts to involve inactive citizens or strategic groups of people in active practices (Baum 2001) such as decision making or knowledge production.

Hence, "participation" in science covers a large diversity of non-scientists (individual citizens, non-governmental organizations, groups of patients, etc.) involvement with the production of scientific knowledge and science governance (Cooper and Lewenstein 2016; Eitzel et al. 2017). Thus, "citizen participation in science" encompasses any form of active non-scientists' participation in the research process to generate science-based knowledge, from setting the research agenda by asking research questions, to collecting data, analysing the results and/or contributing to decision making (Bonney et al. 2009; Lewenstein 2004; Lidskog 2008).

Arnstein (1969) described a "ladder of citizen participation" in political and technical processes that classifies them along a spectrum from non-engagement of citizens to a total commitment. Arnstein starts her analysis with levels of non-participation, then moves to degrees of tokenism with informing, consultation and placation, and finally reaches degrees of citizen power with partnership, delegated power and citizen control.

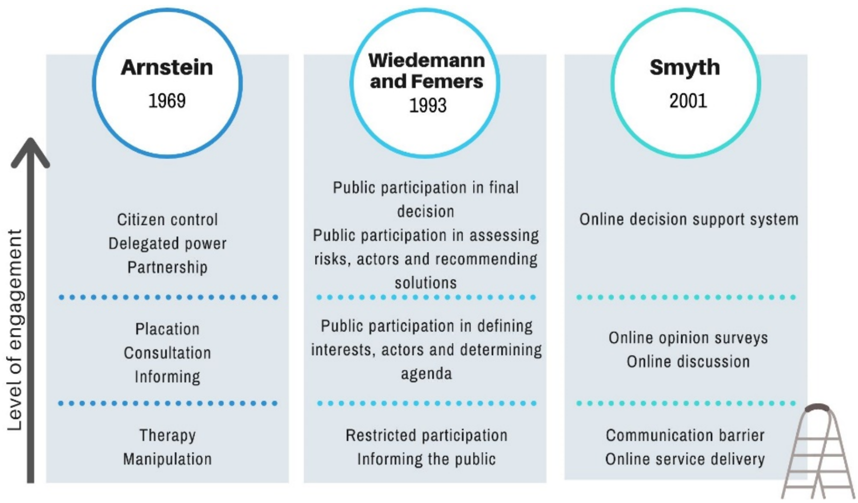


Figure 4. Composition of the ladders of citizen participation proposed by Arnstein (1969), Wiedemann and Fermers (1993) and Smyth (2001). Source: own elaboration.

This ladder focuses on political power relationships but has led to the development of other typologies such as the ones proposed by Wiedemann and Femers (1993) or Smyth (2001) that also classify citizens' role in communication and public participation as a gradient ladder. Wiedemann and Femers adapted Arnsteins' theory to their consideration of environmental decisions about hazardous waste management (Carver 2001). Figure 4 presents a composition of the three ladders:

Moreover, the ladder of participation defined by Smyth (2001) and described by Carver (2001) reflects an online application of Arnstein's ladder of citizen participation. In this approach, Carver also points out that for many organizations the possibility to move to a two-way communication is difficult due to a communication barrier. This barrier is mainly conceived as a sophisticated technology solution that needs to process and analyse information.

Following this categorization of public participation as a gradient Haklay (2013) proposed four levels to encompass the diversity of citizen participation in science (see Figure 5). In terms of understanding participation in scientific research as involvement in all stages of the scientific process, level one is the most basic, while level four is the most comprehensive (Haklay 2018).

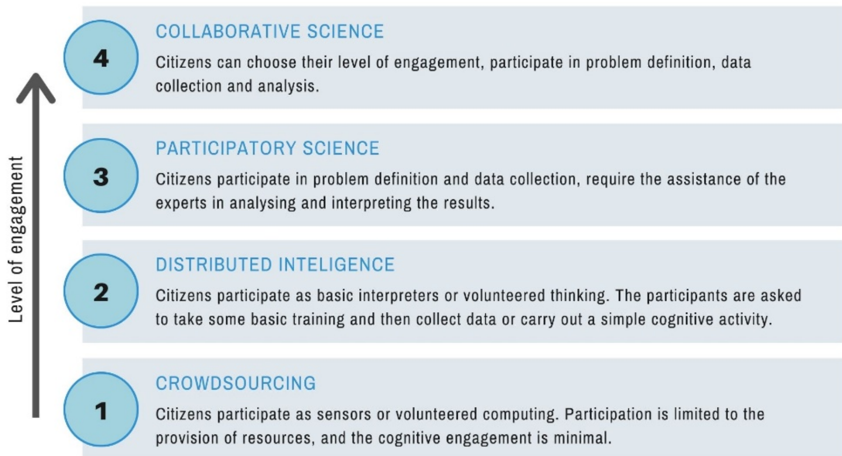


Figure 5. Categorization of public participation in science proposed by Haklay (2013)

Citizen participation in science can be found from participating in crowd-sourcing programmes for collecting data to co-construction of knowledge and of research questions through deliberative processes (Schrögel and Kolleck 2018). The element that remains constant in this participation gradient is the active role of the public and what varies, depending on the level of participation, is the degree of commitment of the participants to the project.

The categorization proposed by Hacklay is very useful, but it 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). However, both Arnstein and Wiedemann and Fermers include this type of participation at the highest levels of their gradient and, therefore, in the levels of greater commitment.

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 that the one included in those levels. Perhaps, such kind of activities fit more at level 3 since participation does not occur throughout the research process.

d) Potential benefits of citizen participation in scientific processes

Participation in decision making that affect individual and collective interests is a basic element of democratic citizenship (Baum 2015). Furthermore, it is a matter of cognitive justice (Irwin 2001) and fulfils the reported will of society to acquire more responsibility in decision making (Rogers 2006).

One of the greatest benefits of citizen participation in science is that if people from different social backgrounds with different personal experiences are given the power to frame research questions it will result in the production of a different kind of knowledge (Strasser et al. 2018). Thus, public participation in research can highlight the "undone science" (Frickel et al. 2010) proposing new research and socially relevant questions in areas that have been largely unexamined scientifically (Strasser et al. 2018).

For example, claims made by women health activists in the 1970s (Kohler 2002), by AIDS patients in the 1980s (Epstein 1995) or by neighbours in the 1990s (Brown 1997) were based on their personal knowledge of their own bodies or physical environment. Their claims had enough value to overcome their professional marginality and challenge scientific consensus (Strasser et al. 2018).

As Alan Irwin (1995) claimed "science should address the needs and concerns of citizens, and seek to meet those needs". Active citizen participation in science implies a research model in which, instead of waiting for these voices to rise when there is a problem, communities are invited to participate and express their concerns from the beginning. In this way, people can bring to science such things as local contextual knowledge and real-world geographic, political, and moral constraints generated outside of formal scientific institutions (Cooper and Lewenstein 2016).

Contrary to the traditional view of science as an arcane activity and of scientists as a closed, elitist circle, approaches that encompass citizen participation in science production open it to society as a means of "democratization of science" (Stilgoe, Lock, and Wilsdon 2014). This requires that in such processes non-scientists contribute to the production of scientific knowledge, often in projects with science education as an associated goal or a by-product (Strasser et al. 2018). Sometimes, this educational objective is necessary for participants to acquire a basic common knowledge (e.g., how to collect data, how to interpret data etc.) before participating. In other occasions, education is a secondary goal associated with the idea of promoting scientific literacy or scientific culture.

The active participation of members from different sectors, and with different forms of knowledge in finding the solution to a given problem helps promote the vision of a shared future (Jacobi et al. 2017), as well as a better understanding of scientific and technological processes (Stilgoe, Lock, and Wilsdon 2014). This participatory research approach may foster a citizenship that embraces science and technology, empowers the public to critically use the scientific tools to solve some of its problems and promotes scientific modes of reasoning among citizens (Strasser et al. 2018).

Also, citizen participation in research improves the feeling of belonging by all members (Calder 2002), and can make decisions more knowledgeable and legitimate for science governance. For example, Bernauer and Gampfer (2013) reported that the popular legitimacy of global climate governance decreases when civil society is excluded and increases when civil society is added. Similar results were reported by Doh and Guay (2006) regarding environmental institutions in Europe and in the United States, combining the activism of non-governmental organizations with their corporate strategies to meet their social responsibilities.

Taking all this into account, seems that a more participatory approach in the investigation process and its governance is not only necessary to achieve real democracy, but can also be beneficial for the scientific output itself. It is important to keep in mind that the opening of science to society (and vice versa) implies a change in the research system and, of course, in the roles of the different actors involved. In conclusion, more research in this area is needed in order to better understand the present situation and propose strategies to effectively foster citizen participation in science.

e) Challenges and limitations of citizen participation in science

Despite all the potential benefits of including society in the science and technology system, there are also some challenges or limitations of citizen participation in science. Perhaps the greatest challenge of this kind of initiative lies in the development of collective and integrated knowledge among scientists and the other stakeholders included in the research process (Cornell et al. 2013; Jacobi et al. 2017).

To do so, a key aspect is to establish fruitful relationships between the different stakeholders involved. In such processes the need for direct engagement between scientists and the public increases, especially in higher levels of participation (Haklay 2013). In this context, it is paradoxical that most scientists have never received training on communication skills, public engagement methodologies and/or how to establish collaborative relationships (Brownell, Price, and Steinman 2013; Revuelta 2018). Therefore, their intuition, innate capacity for such tasks, or experience will determine their ability to participate in these activities (Revuelta 2018). In current literature, the risk of this situation has been highlighted and the need to promote such kind of training to scientists has been raised (Leshner 2007; Mulder, Longnecker, and

Davis 2008; Rensberger 2009; Revuelta 2018; Sharon and Baram-Tsabari 2014).

Furthermore, most researchers have not been trained in the epistemology of science and, generally, have spent most of their time studying and producing science, so they have not had the opportunity to reflect deeply on the relationships between science and society (Duschl and Grandy 2013). Therefore, in addition to training future generations of researchers in communication strategies, it would also be interesting to train them in the nature of science to promote this change in the science and technology system. The term "nature of science" usually refers to questions about what science is, how it works, what its epistemological and ontological foundations are, as well as the features of scientists' work as a social group and science-society relations and influences (Acevedo Díaz, García-Carmona, and Del Mar Aragón 2016). The sociological aspects of the nature of science are also present in the reasoning, arguments and decisions of people when they face current scientific questions that affect them on a daily basis (García-Carmona, Acevedo-Díaz, and Aragón 2018). Therefore, acquiring this type of knowledge seems adequate not only to have a better understanding of science and its publics, but also to train scientists capable of successfully carrying out citizen participation projects in science.

A lack of some resources also challenges citizen participation in science. In such participatory projects scientists need to play their role as experts but also act as facilitators and be devoted to perform more demanding conceptual work than in their routine tasks (Haklay 2013). Moreover, participatory projects are more time and energy demanding (Powell, Colin, and Powel 2009). Consequently, the research process usually is slower relative to more traditional research projects. Hence, it is necessary to assign specific human and financial resources to tasks that are not included in researchers' regular work (Kullenberg and Kasperowski 2016). Institutional support is also needed in order to sustain this kind of projects (Powell, Colin, and Powel 2009).

Scientific output is not always the main goal of citizen participation projects. As a consequence, scientific results may not be published in a traditional way (e.g., scientific journals) and they can fall outside the scope of scientific and scientists evaluation (Kullenberg and Kasperowski 2016). For science participatory processes to make a difference, such activities must become part of the researchers routine practice and also need to be professionally recognized (Besley et al. 2018; Sanz Merino and Tarhuni Navarro 2019).

Often, in such projects participants do not represent a wide range of groups, interests or perspectives (Ott and Knopf 2019). Unfortunately, there are limited surveys of participatory projects aiming to analyse the participants profile. Still, those available are from online projects where participation is decentralized and suggest that the participants are predominantly white, young and middle class men (Curtis 2014; Raddick et al. 2010; Reed et al. 2013). Hence, special efforts are necessary to recruit participants and design broadly representative processes in which all participants exercise similar power (Baum 2015).

In 2006 Nielsen framed the 90-9-1 rule for participation inequality. According to him the proportion of registered people in social media or online communities who do not contribute can reach 90% of the total number of participants. Of the remaining participants, 9% contribute infrequently and just 1% contribute most to the knowledge production. Other authors claim that such participation inequalities are also present in both online and offline participatory projects (Haklay 2018; Jennett et al. 2016; Strasser et al. 2018).

On the positive side, in this pattern of participation some citizens are highly committed and they are not just contributing to the project, they are also becoming experts (Jennett et al. 2016). On the negative side, such inequalities demonstrate that deep citizen commitment is limited and, even in the most successful projects, the actual number of participants that are highly engaged is small (Haklay 2018; Strasser et al. 2018).

Moreover, constant demands for community consultation and engagement in participatory processes without an adequate return may result in "consultation or participation fatigue" which may deter citizens from participating in future projects (Hayward, Simpson, and Wood 2004; Porlezza 2019). Thus, it would be necessary to take actions to avoid duplication of resources and effort, and establish transparent procedures to use the findings of previous and similar projects (Rasheed and Abdulla 2020).

Of course, more research is needed to fully understand these hurdles and propose possible solutions to overcome them. Some of those limitations are analysed in chapters 3, 4 and 5.

1.2.3 Main actors of participatory practices in science

Below, an analysis of the main actors involved (scientists, civil society and other stakeholders such business sector and policy makers) and their roles in such participatory processes is presented.

a) Scientists

In any kind of research process, the role played by science practitioners acting as experts is decisive. But they are not only a key actor in scientific production, scientists are also increasingly present in the field of public communication either acting as sources of information or directly as communicators. The citizen participation in science processes require a change in the traditional researchers-public relationship during the research process. And, as we have seen, science communication is a key tool for the proper development of this type of project.

Greater experience in public engagement activities is associated with a better understanding of the public and with a more open-minded view on how communication with other stakeholders should be structured (Besley and Nisbet 2013; Davies et al. 2009). Scientists' that have a better understanding of publics prefer dialogical or two-way communication approaches rather than the idea of filling a knowledge vacuum (Besley and Nisbet 2013). This type of more deliberative approach is what is needed to carry out participatory scientific production processes.

Despite science communication activities being organized and managed by communication professionals, the participation of scientists is also expected (Bauer and Jensen 2011). Researchers' participation in public engagement activities is one of the things that the public values most, because they talk from a first person perspective and with a deep knowledge of the topic (Revuelta 2014). However, the vast majority of professionals from scientific disciplines have never received training in science communication, public engagement or collaborative strategies (Brownell, Price, and Steinman 2013; Revuelta 2018).

In addition to this lack of training, other barriers can restrain the participation of scientists in participatory processes such as lack of time, lack of support and lack of professional recognition (Sanz Merino and Tarhuni Navarro 2019; Besley et al. 2018; Illingworth and Roop 2015; Gascoigne and Metcalfe 1997). As a response, numerous initiatives have been issued to support scientists' involvement in public engagement. These initiatives range from adding dissemination requirements to grants to creating a more favourable social and professional context for science-society relationships (Palmer and Schibeci 2014). For example, rewarding researchers for their public engagement activities or using it as an evaluation criterion.

Moreover, there are other contextual factors which may be disincentives to the involvement of researchers in participatory processes. For example, the increasing competitiveness in the research sector forces scientists to spend more time on research and publication work and the growing efforts necessary for scientists to get funding. In addition, the so-called "Carl Sagan Effect" is still in force. It means that it is still thought that if researchers participate in outreach activities, they are losing their time, or that they are doing it simply to attract attention. Fortunately, this negative view is disappearing, especially among youngest scientists (Besley et al. 2018).

On the other side, Besley and Nisbet (2013) reported that scientists strongly believe they should have an active role in public debates, especially with policy makers. Bentley et al. (2012) studied the situation with climate change scientists and reported similar results especially when a substantial disjoint may exist between scientific findings and the impact they have on the public.

There is a need for exploratory research to better understand the interaction between scientists and the public. If citizen participation in science is going to be promoted, we need to understand researchers' views, opinions and attitudes towards the public and their role in public engagement activities.

b) Civil society

It is clear that when we talk about citizen participation in science, citizens themselves are a central actor in this research model. However, involving individual citizens in science production and governance is not always the most effective approach. That is why many of the participatory approaches propose organized civil society as one of the main stakeholders.

Civil society organizations (CSOs) can act as platforms that collect social opinions and as spokespersons of society's concerns. According to Hojnacki (1999) stakeholder theory, CSOs can develop power, urgency, and legitimacy. Thus, we can consider that CSOs are important actors who can realize the promise of participatory research being responsive to the real world (Smismans 2008).

Moreover, CSOs can be seen as "alliance-brokers between public and policymakers" (Mercer and Green 2013). Thus, such organizations may be able to use their position to influence the resolution of public policy issues including those related to science and technology (Rainey, Wakunuma, and Stahl 2017).

According to the European Science Foundation (2013), CSOs expertise should be included at the research project level. Not only to fulfil the traditional CSOs' dissemination role to the public (Mercer and Green 2013) but also to benefit from the sectoral knowledge and oversight that CSOs can provide in research (Ahrweiler et al. 2019; Bernauer and Gampfer 2013). Furthermore, establishing arenas that promote scientific dialogues to unite scientists with other social actors offer the opportunity to understand and jointly analyse global problems in order to inform decision making (Malyska, Bolla, and Twardowski 2016; Welp et al. 2006).

In the last decade, there have been several initiatives to stimulate public participation in research and to embed participative processes in research governance (European Commission, 2014). However, despite being a central actor in participatory approaches, the term "civil society organization" is not well defined (Ahrweiler et al. 2019; Rainey, Wakunuma, and Stahl 2017). There are terms such as "voluntary", "third sector", "charities" or "non-governmental organizations" that have similar and/or overlapping characteristics that may be regarded as CSOs (Nugroho 2011).

Also, and more worryingly, there is no consensus of the specific roles that CSOs should play in research (Steen-Johnsen, Eynaud, and Wijkström 2011). Nevertheless, Ahrweiler et al. (2019) reported that the CSOs' role in research and innovation projects is much more multifaceted (e.g., data providers, providers of access to the research field, providers of specific domain expertise, etc.) than is currently assumed.

On the other side, other authors have questioned the involvement of CSOs in science. For example, Krabbenborg and Mulder (2015) claimed that the role of "early warning of potential risks" given to CSOs and their activism as "opponents of scientists" and "developers of negotiation technology" can be problematic in the early stages of open discussions. Indeed, De Saille (2015) calls attention to the power differences between CSOs. Likewise, Taminiau (2006) and Elzen *et al.*, (2011) consider that CSOs are not very influential by themselves. Rather, they are only influential when they work together with other actors such as policy-makers, companies or regulators (Elzen et al. 2011).

However, what really matters is that if citizen participation in science is going to be a reality, CSOs are a necessary key actor. Thus, it is necessary to understand this actor (at local and global level), their perceptions about their role in scientific production, and the limitations and needs that must be solved to promote their involvement.

c) Other key stakeholders

The potential of research and innovation as transforming elements is unquestionable. That is why numerous political strategies have focused their efforts on increasing and improving their research and innovation systems, thereby increasing capacities of the country or region.

According to the quadruple helix model of innovation (Carayannis and Campbell 2009), all sectors play an important role in this knowledge society. Thus, in addition to scientists and civil society, there are other important stakeholders to consider in science and its governance. It means that the role of the private or business sector and policy makers are also relevant in the processes of science and technology knowledge generation.

Exploring how the business sector relates to scientific and technological information can offer a useful explanatory framework, not only to describe the map of the current situation, but also to identify possible barriers to research and innovation carried out by companies or used by them. This will be crucial for the alignment between the needs and values of different actors (including society and academia) and the processes in which the business sector participates. This last aspect is closely related to the idea of co-responsibility and co-creation on which the concept of RRI is focused (Von Schomberg 2011).

Both RRI and the quadruple helix approaches consider science governance a key output of citizen participation projects. Thus, policy makers and public administration representatives must be involved as a relevant actor. Moreover, many citizen participation practices do not have scientific output as their main goal, the first objective usually consists of providing scientific evidence to influence political decision making or propose an operational solution to a problem (Kullenberg and Kasperowski 2016).

However, this thesis assesses this issue mainly focusing on an exploratory analysis of Spanish scientists' (Chapter 4) and Spanish civil society's (Chapter 5) perceptions. Of course, more research is needed regarding the abovementioned other key stakeholders to fully understand the Spanish situation.

1.2.4 Brief summary of the Spanish context

The history of science-society relations in Spain is closely related to the science system history itself. It was not until the definitive end of the dictatorship in 1975, with Dictator Franco's death, that Spanish democracy started.

Democracy facilitated the country's entrance to the European Union and consequently Spanish science became internationalized and able to access European funding. The Spanish autonomous communities implemented their own research, development and innovation (R&D&I) plans. The *Ley de la Ciencia* (Spanish Law of Science) contributed to the professionalization of research and access to regular funding. Spanish science entered the international circuit, becoming increasingly competitive. Between 1981 and 2003 the number of scientific publications signed by Spanish authors indexed in the Institute for Scientific Information (ISI) increased from 3382 to 24737 (Gómez et al. 2006). The investment in R&D&I increased from 0.43% to 1.1% of gross domestic product (Gómez et al. 2006). Research centres and universities also increased their communication to the media (press releases, interviews, etc.) because they were more productive in research and were competing more strongly among themselves. Consequently, mass media disseminated more than before the achievements of Spanish scientists to society.

During the 1990s and the beginning of the 21st century large science infrastructures were built, more resources were invested in research, and good working conditions attracted high-level scientists back to the country. This budgetary growth was halted by the economic crisis that began in 2007 which lasted a long time in Spain (Regalado 2010). The new Law of Science was established in 2011 and proposed a series of actions to ensure that research is given enough resources and autonomy but many of the key points have not been complied with and the Spanish science system remains economically weakened (Pain 2013). Terms such as "science communication", "the public communication of science" or "science journalism" were practically unknown in the country prior to the last decade.

In the last two decades, there have occurred some changes in Spain's approach towards science and society integration. In 2007 the Spanish Foundation for Science and Technology (FECYT), a public agency from the Spanish Government, constituted the Spanish Scientific

Culture Units (UCCi). These are structures formally recognized by the Spanish government and integrated into universities, research centres or entities in the research and development system. Amongst the main functions of these units are the communication of research and innovation results, the general dissemination of scientific and technological knowledge, the guidance and training of research personnel in the dissemination of science, and the research on science communication, public engagement or science-society relationships (Lopez and Olvera-Lobo 2017). These units are key agents in the dissemination of science and innovation in Spain and provide a crucial service for improving and contributing to the training, culture and scientific knowledge of citizens (Capeáns, López, and Gonzalo 2012). At present there are 79 UCCi in Spain (Lopez and Olvera-Lobo 2017).

Moreover, since 2009 the FECYT launches each year a national call to fund projects to promote scientific culture. This call is still the main instrument for science communication and promotion of scientific culture projects in Spain (Lopez and Olvera-Lobo 2017). Despite the increase in efforts towards dissemination in recent decades, Spain is still one of the European countries with least scientific culture (OECD 2016).

Public organizations in Spain now more often target public engagement. However, the inclusion of citizens in science and technology production is not as developed as in some other European countries (MoRRI consortium 2018). For now, scientists' involvement in scientific participatory projects is not included as an evaluation criterion. Thus citizens are involved only to a minor extent, and the organizational landscape enabling engagement of citizens is not well developed (MoRRI consortium 2018).

Nevertheless, the tendency is to align Spain's strategy with the European guidelines to move towards a deeper inclusion of society in the scientific process (Hockfield 2018). The European Union strategy is to move towards a deeper inclusion of society in the scientific process. In this context, the analysis of citizen participation in science activities in Spain and the impressions of the different actors involved are needed for a better understanding, but also to be able to propose effective strategies to foster such relationships.

1.3 Objectives and hypothesis

This thesis hypothesises that most researchers do not know their public or the utility of involving them in science. Civil society organizations neither know the science and technology system, nor their potential or how they can intervene in it. Only if we know the opinions and attitudes of both actors, can we develop tools to foster the effective implementation of citizen participation in science.

Thus, the general objective of this thesis is to analyse the characteristics of current citizen participation in science activities and the opinions and attitudes of the actors involved. The specific objectives are as follows:

1. To identify current good practices of citizen participation in science activities and analyse their characteristics.

2. To identify the researchers' perception on the knowledge and attitudes of Spanish citizens regarding science. To contrast them with data from the FECYT biannual survey of public perception of science.

3. To analyse the opinions and attitudes of Spanish researchers on public engagement in science.

4. To analyse the opinions of Civil Society Organizations (CSOs) managers on their role in the Spanish research process.

1.4 Structure of the thesis

In order to achieve the general objective and the four specific objectives, as well as to test the hypotheses formulated in the previous section, the author of this thesis has carried out an investigation that has been divided into three studies. The overall methodology used is described in Chapter 2.

Following the compendium thesis modality, each study has been presented in an independent chapter (Chapter 3-5) which together form the block results of this thesis. Each of these chapters corresponds to an article of a peer-reviewed journal, either published, currently in press or under review.

At the beginning of each chapter, a page with the exact reference of the journal in which these studies have been published, or in which they are being reviewed, has been included. The author of this thesis is the first author of all publications.

This thesis has been carried out from October 2016 to July 2020. However, the studies presented are not organized chronologically but according to the objectives to which they respond and to give cohesion to the argumentation of the doctoral thesis. Table 1 gives an overview of the three chapters that present thesis' results, the objectives to which they respond and the journal in which are submitted.

	Title	**Objective**	**Journal and status**
Chapter 3	Characteristics of Spanish citizen participation practices in science	Obj. 1	Journal of Science Communication (under review)
Chapter 4	Scientists' opinions and attitudes towards citizens' understanding and their role in public engagement activities	Obj. 2 & 3	PLOS ONE (published)
Chapter 5	Social participation in science: perspectives of the Spanish civil society organizations	Obj. 4	Public Understanding of Science (accepted)

Table 1. Outline of the structure of thesis' results and their relation with thesis' objectives

Following the results block, there is a joint discussion of the overall research (Chapter 6), a conclusions section (Chapter 7) and a final section with a reflection on thesis contributions and future impacts (Chapter 8).

CHAPTER 2. METHODS

"Every so often, in the midst of chaos, you come across an amazing, inexplicable instance of civic responsibility."

Kurt Vonnegut
Writer

2.1 Context

Throughout this thesis, citizen participation in science in the Spanish context has been studied. This is interesting on the one hand, to gain a better understanding of the science-society relationship in Spain, a country very active in scientific research and which is recently promoting the inclusion of society in the research process. And, on the other, to allow comparisons with other research in countries with similar social realities to see the situation they are in, detect deficiencies or strengths, points of improvement etc.

2.1.1 Participants

This thesis had a total of 1069 participants. The individuals that collaborated with this study have different profiles. 16 participants are coordinators of citizen participation practices carried out in Spain during the period 2015-2017. Furthermore, 1022 participants are researchers living and working in Spain participating in research and development projects funded by the Spanish Ministry of Science, Innovation and Universities during 2013 and 2014. Finally, 31 CSOs managers or delegated representatives with decision making power also collaborated with this thesis. In all three studies the gender perspective and the geographical distribution have been taken into account in the composition of the sample. Table 2 summarizes the sample.

Chapter	**Participants**	**Description**
Chapter 3	16	Coordinators of citizen participation practices (2015-2017)
Chapter 4	1022	Researchers participating in research projects funded by the Spanish Ministry of Science (2013-2014)
Chapter 5	31	CSOs managers or delegated representatives (2017)

Table 2. Summary of the sample

2.1.2 Advisory boards

An advisory formed by members of different Spanish scientific culture units (Capeáns, López, and Remiro 2012) was constituted for each study of this thesis. In chapters 3 to 5 a detailed description of the advisory board composition and contributions to the study is included.

However, in all studies, these units were key due to their local knowledge of the reality within different parts of the country. But also especially due to their ability to contact the study subjects (e.g., researchers), identify CSOs managers and propose good practices of citizen participation in science to be included in the studies.

2.2 Data collection instruments and analysis

Qualitative methodologies (semi-structured interviews) and quantitative methodologies (online questionnaires) have been used. Chapters 3 to 5 explain in detail the methodology of each study. In each chapter the reason for having selected one or another methodology is explained, as well as the specific details of its application and analysis. This section therefore presents a general summary.

2.2.1 Data collection instruments

Different data collection instruments have been used for the purpose of each study of this thesis:

- Semi-structured interviews were used as a qualitative data collection instrument to deep in individuals' perceptions on different issues.

- Anonymous online questionnaires with quantitative closed questions were delivered and collected to assess researchers' perceptions of the public and their role in public engagement.

a) Semi-structured interviews

Each interview protocol was developed in close consultation with the advisory board and intentional sampling was used to select the interviewees (see Chapter 3 and Chapter 5 for more detailed information). Once the interviewees were identified, we sent them an e-mail describing the project and invited them to participate in an interview. Up to three follow-up emails and/or phone calls were made to solicit participation from those who did not respond.

Before participating, all interviewees were informed of the nature of the study and the data processing policies, and they freely gave their consent. All of them were free to answer each one of the questions as well as to stop participating at any time. All the interviews were conducted between June 2017 – July 2018. The average interview took 48 minutes to complete, with the range spanning from 25 minutes to 78 minutes. All of them were recorded and naturally transcribed; once the first draft of the transcription has been made, all irrelevant sounds were eliminated, as well as grammatical errors when speaking, doubts, filler words, pauses or unnecessary repetitions. This is the most common type of transcription of qualitative research.

b) Online questionnaires

The specific questions of the survey were developed in close consultation with the advisory board. The survey design incorporated the key indicators and certain questions used in surveys on public understanding of science, such as those carried out every two years by the FECYT in 2016 or the Science and Engineering Indicators report, published by the National Science Board of the United States in 2018, in order to be able to compare the answers. The survey also included new questions to provide a broader knowledge as well as certain socio-demographic questions (see Chapter 4 for more detailed information).

The questionnaire was accompanied by an informative email specifying the purpose of the study and the use that was to be made with the data that the participants provided. Respondents were free to choose whether or not to answer any particular question. Before submitting their answers, respondents had to check that they have received informed consent. The average survey duration was approximately 15 minutes.

2.2.2 Inductive qualitative content analysis

The inductive qualitative content analysis approach was used in order to analyse the qualitative data from the semi-structured interviews with the support of the research software Atlas.ti (versions 7.5 and 8.4). This approach is a technique to classify written or oral materials into identified categories or similar meanings. It is based on the interpretation of the content of text data through the systematic classification process of coding and identifying categories or patterns to describe the meaning of qualitative material (Schreier 2012). This methodology is useful to represent a systematic and objective description of the phenomena.

A sequential analysis of the interviews was carried out, and observational notes were included in the transcription of the interviews. All the qualitative data of this thesis has been reduced to codes or concepts that describe the research phenomena by creating categories, i.e., groups of content that share a commonality (Elo et al. 2014). The specific categories presented in the results section have been inductively determined from the interview data.

Investigator triangulation and peer debriefing were the strategies used to ensure reliability. This first strategy involved the use of more than one researcher during interview analysis to have a more detailed and balance picture of the situation. The thesis author and a member of the research team worked as coders in coding the interview transcripts. They first coded a sample of interviews as a means of calibration, then worked independently achieving a high degree of reliability. Discrepancies were discussed and resolved between coders and the thesis co-directors.

Peer debriefing was used to ensure the collection of valid information. The first author did the first round of analysis of the code compiles, the thesis co-directors reviewed the analysis and added their interpretations. The joint categorization resulting from this process was shared with the corresponding advisory board and presented in internal seminars with the research team. Their inputs and feedback were also integrated into the final results analysis.

2.2.3 Statistical analysis

All quantitative data of this thesis has been analysed by univariate and bivariate analysis using a descriptive statistical approach. Moreover, to analyse the correlation between the quantitative variables a Pearson's chi squared test has been performed. In all cases, the used statistical software was Statistical Package for the Social Sciences (SPSS), version 23.

Throughout the entire study, the variables gender, age or field of research have been analysed for each of the questions included in the online questionnaire (see Chapter 4 for more detailed information).

CHAPTER 3. CHARACTERISTICS OF SPANISH CITIZEN PARTICIPATION PRACTICES IN SCIENCE

Manuscript

Llorente, C. Revuelta, G. Carrió, M.
Under review in Journal of Science Communication

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 participation, Participation and science governance, Public engagement with science and technology

3.1 Context

During the past decade, the involvement of non-scientists in research 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., 2018; Hockfield, 2018).

The science-society relationship has been promoted by distinct movements for the democratisation of science, such as the "responsible research and innovation" (RRI) model, based on the concept of shared responsibility (Stilgoe, Owen, and Macnaghten, 2013). Similarly, the "quadruple helix model of innovation" considers society the fourth and principal actor in the innovation system, together with science, policy and industry (Carayannis and Campbell, 2009; Schütz, Heidingsfelder, and Schraudner, 2019); while the "open science" movement seeks to make scientific data and production accessible to everyone (Vicente-Sáez and Martínez-Fuentes, 2018; Woelfle et al., 2011).

In the last few years, a number of changes have occurred in Spain's approach to integrating science and society. However, the inclusion of citizens 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).

Participation in decision-making that affects individual and collective interests is a basic element of democratic citizenship (Baum, 2015). Furthermore, it is a matter of cognitive justice (Irwin, 2001) and fulfils the reported will of society to acquire more responsibility in decision-making (Rogers 2006). Potential benefits are associated with the promotion of such science-society relationships.

For example, the active participation of members from different sectors and with different areas of knowledge in finding the solution to a problem helps to promote the vision of a shared future (Jacobi et al., 2017), and improves understanding of scientific processes (Stilgoe, Lock, and Wilsdon, 2014a). Citizen participation in research increases feelings of belonging (Calder, 2002), shines a spotlight on new research and socially relevant questions (Frick el et al. 2010), and enhances knowledge and legitimacy in science governance decision-making (Bernauer and Gampfer, 2013).

The inclusion of civil society organisations (CSOs) in scientific processes is useful to gain the sector knowledge and broad view that civil society organisation research can provide (Ahrweiler et al. 2019; Bernauer and Gampfer 2013). Moreover, by establishing scientific dialogues that connect researchers to social actors, representatives of companies, CSOs and politicians are given the opportunity to come together to analyse and understand global problems and make decisions accordingly (Malyska, Bolla, and Twardowski 2016; Welp et al. 2006). Citizens themselves can also reap potential benefits from such participatory processes, acquiring skills, knowledge, social capital, and power (Baum, 2015).

However, 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.

3.1.1 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. Citizens may be individuals, organised communities such as CSOs, or even companies or professional associations. using the term "public" or "citizen", it is important to consider that we are actually talking about "multiple publics" (Besley and Nisbet, 2013).

Participation, on the other When hand, 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).

The relationship between citizens and science has shifted from deficit to dialogue (Smallman, 2018). 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 are usually 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, 2014b).

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).

The diversity of these 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 2018). Haklay (2013) proposed four typologies to classify citizen participation in science, which are summarised in Table 3:

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.

Table 3. Levels of citizen participation in science proposed by Haklay (2013)

3.1.2 Multiple objectives of citizen participation in science

The principal goal of many citizen participation science practices is not the production of scientific output. Rather, the first objective often consists of creating 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, 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). 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; S. R. 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, Colin, and Powel 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).

Most participatory projects, therefore, tend to pursue multiple objectives: scientific, socio-political and, often, educational.

3.1.3 Challenges of citizen participation in science

The greatest challenge of this kind of initiative lies in developing collective and integrated knowledge among scientists and other stakeholders included in the research process (Cornell et al. 2013; Jacobi et al. 2017). Participants in participatory 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).

Constant demands for community consultation and engagement in participatory processes without an adequate return may result in consultation or participation fatigue, which may deter citizens from participating in future projects (Hayward, Simpson, and Wood 2004; Porlezza 2019). It will be necessary 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).
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).

Participatory science projects are often time and energy intensive, requiring institutional support to sustain them (Powell, Colin, and Powel 2009). Especially where scientists need to act as facilitators as well as experts, and perform more demanding conceptual work than mere routine tasks (Haklay 2013), the research process tends to be slower and specific resources (both human and financial) need to be allocated to tasks that are not part of the scientists' regular work (Kullenberg and Kasperowski 2016).

In this context, it is paradoxical that the vast majority of scientists have never received training in communication skills, public engagement methodologies, or how to establish collaborative relationships with non-scientists involved in scientific initiatives (Brownell, Price, and Steinman 2013; Revuelta 2018). The current literature has drawn attention to the risks of this situation and the need to promote the provision of training to scientists (Leshner 2007; Mulder, Longnecker, and Davis 2008; Rensberger 2009; Sharon and Baram-Tsabari 2014).
Given that scientific output is frequently not the only objective of this type of citizen participation project, 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). For participatory science processes to make a difference, such activities must become part of the researchers' routine practice and must also be professionally recognised (Besley et al. 2018; Sanz Merino and Tarhuni Navarro 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. 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.

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 citizen participation practices?
>
> RQ2: What is the role of communication in these practices?
> RQ3: To what extent are the key requirements incorporated in citizen participation practices?

3.2 Methods

To answer these questions, we conducted 16 semi-structured interviews with coordinators of citizen participation practices carried out in Spain from 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 4).

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

Table 4. Entities to which the advisory board belongs

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.

3.2.1 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 (Lopez 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. 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 5).

No.	**Coordinator profile**			**Practice description**
	Gender	**Occupation**	**Sector**	**Practice description**
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 organisatio n	*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.
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 communicat or	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 administrat ion	*Level 1:* Research project on climate change. Participants install weather stations in their homes and provide data.
12	Female	Manager	Civil society organisatio n	*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	Scientific sector	*Level 3:* Research project on the prevention of sexually

		engagement projects		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.

Table 5. Sample description

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.

3.2.2 Data collection and processing

The research team developed a semi-structured interview protocol (see Figure 6) 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 42 minutes to complete, within a range from 25 minutes to 73 minutes. All the transcriptions were reviewed by the authors.

RQ1	• What kind of people participate in the activity? Was there more than one actor?
RQ3	• What does the practice of citizen participation consist of? What did the participants have to do? • What have been the outputs of this practice? Have they been integrated in any way into the science and technology system? • Was the activity or its methodology replicated in another context, country or time? • Have you implemented any kind of assessment or monitoring of the participation? How did you do this assessment?
RQ2	• What was the role of communication in this practice?

Figure 6. Interview protocol

3.2.3 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). Triangulation, peer debriefing and member checking were the strategies used to ensure reliability.

3.3 Results

3.3.1 Stakeholders involved in citizen participation practices in science

From the interviews, we identified three kinds of stakeholders involved in citizen participation practices in science; we summarize them in Table 6.

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 make the decision to participate in the project themselves, usually students, as stakeholders involved in the practice.	8/16
Generic audience	References to generic groups of people (e.g., general public or interested persons) as stakeholders involved in the practice.	1/16

Table 6. Qualitative results of the stakeholders' involvement in citizen participation practices in science, analysed through a categorization system

a) 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.

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 same category because they all identify a strategically selected audience to achieve the objectives of the practice.

b) 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 taking part in the activity as part of their educational process.

c) 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)

3.3.2 Communication role in citizen participation practices in science

In this section, we have included all the answers that interviewees gave us about the role of communication in their participatory activity (Table 7).

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

Table 7. Qualitative results of the communication role in citizen participation practices in science, analysed through a categorization system

a) 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 came across 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.

b) 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.

3.3.3 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 practices. Table 8 offers an overview of the analysis of the 16 interviews. Throughout the interviews, we identified a fifth requirement, the training of participants and facilitators, which was not covered in the original protocol.

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

Table 8. Qualitative results of the degree of integration of the different key requirements for citizen participation practices in science, analysed through a categorization system

a) 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)

b) Levels of participants' 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).

c) 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)

d) Training of participants and/or 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)

e) 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)

3.4 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 will offer interesting 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. However, given that this is a qualitative and exploratory study, our findings cannot be considered representative of all Spanish citizen participation practices.

3.4.1 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, 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. 2018).

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.

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 et al. 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.

3.4.2 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.

A participatory science process needs to be understood as a two-way commitment. 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.

3.4.3 Degree of integration of the 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 2018). 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 et al. 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.

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.

3.5 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 overinterpreted. 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.

CHAPTER 4. SCIENTISTS' OPINIONS AND ATTITUDES TOWARDS CITIZENS' UNDERSTANDING AND THEIR ROLE IN PUBLIC ENGAGEMENT ACTIVITIES

Paper published at:

Llorente C, Revuelta G, Carrió M, Porta M (2019) Scientists' opinions and attitudes towards citizens' understanding of science and their role in public engagement activities. PLoS ONE 14(11):e0224262. https://doi.org/10.1371/journal.pone.0224262

Abstract:

The increasing perception that public communication in science and technology is an important tool to create a knowledge society is encouraging numerous public engagement activities. However, too little is known about scientists' opinions of and attitudes towards the

public with whom they interact during these activities, especially in southern European countries such as Spain. If we want to establish an effective dialogue between science and society, we need to be aware of the opinions and perceptions that both parties have of each other. In this study, we address this issue by focusing on 1022 responses to a survey conducted among scientists in Spain to discover their views of the public, and we then compare these responses with data from other national surveys on the public's understanding of science.

The results show that approximately 75% of Spanish scientists think that the general public has a serious lack of knowledge and understanding of scientific reasoning, although scientists do recognize that science interests the public (73%). Scientists believe that the public values the scientific profession to a lesser extent than suggested by public surveys: on a scale of 1–5, survey respondents rate their valuation of the scientific profession at 4.22, whereas scientists rate the public's valuation of the profession at 3.12, on average. Significant differences were detected between scientists' perceptions of how citizens are informed about science and what citizens report in surveys. The challenge for the future is to narrow this gap in order to help scientists gain a better understanding of the public and their interests and to make public engagement activities more effective.

4.1 Introduction

Scientific innovations are deeply embedded in social life: in the economy, in policy choices, and in how people care for themselves and how they use environmental resources. It is primarily for this reason that public communication in science and technology is increasingly seen as an important tool for creating a knowledge society. Indeed, in recent years, great importance has been placed in Europe on outreach and science dissemination activities (European Comission 2014; Felt 2007; Hockfield 2018), and most strategic documents describing research and development of the European Union and its member countries (including Spain) highlight the need to establish a dialogue between citizens and scientists (Felt 2007; Van der Hoven et al. 2013). Over the last two decades, as interest in involving the public in research and innovation processes has increased, so has concern that these processes be implemented responsibly. This movement of responsibility, labeled responsible research and innovation (RRI), has been defined by Stilgoe et al., (2013) as "taking care of the future through collective stewardship of science and innovation in the present".

Public communication of science tends to adopt different approaches that can be grouped into three models: dissemination model, dialogue model and conversation model (Trench 2008). The last model can be understood as "public engagement with science" and refers to a wide range of interactions that provide opportunities for mutual learning between scientists and members of the public (European Commission 2007). Mutual learning refers not just to the acquisition of knowledge but also to increased familiarity with a wide range of perspectives, frameworks, and worldviews (Von Schomberg 2011). The challenge is therefore to encourage a deeper and more systematic engagement with civil society groups and the wider public.

For public engagement to make a difference, it must become part of the routine practice of this new concept of responsible science (European Commission 2007). Despite the fact that calls for funding research (both from Europe and the Spanish government) increasingly include communication as a key issue, researchers' involvement in such activities remains voluntary (Revuelta 2018). Moreover, most researchers do not receive specific training in these areas either as undergraduates or during their subsequent training as scientists (master's, doctorate, etc.)(Besley et al. 2018; Brownell, Price, and

Steinman 2013). Therefore, most researchers do not have specific consistent knowledge about effective strategies of scientific communication or about studies of social perceptions of science (Revuelta 2018). Therefore, their intuition, innate capacity for such tasks, or experience will determine their ability to participate in these activities. A substantial number of changes in Spain's approach towards integrating science and society have occurred in the past few years. For example, public organizations in Spain now more often target public engagement. However, the inclusion of citizens in science and technology is not as developed as in some other European countries (MoRRI consortium 2018). Public engagement is not an evaluation element, citizens are involved in research and innovation to a minor extent, and the organizational landscape enabling engagement of citizens is not well developed (MoRRI consortium 2018). Nevertheless, the tendency is to align Spain's strategy with the European guidelines.

The European Union strategy is clearly to move towards a deeper inclusion of society in the scientific process. In this context, public engagement activities are key, as is the willingness of scientists to take part. If the scientific community wants to establish an effective dialogue between science and society, it is important to be aware of the opinions and perceptions that both parties have of each other.

In this study, we address the issue of mutual opinions and perceptions by focusing on Spanish scientists' views of the public and their role in public engagement activities. We compare these views to the results of previous national surveys on the public's understanding of science from Spain and from Europe. We use the term "scientist" to refer to the broad range of individuals from across scientific, medical and engineering fields who are working in research and employed by universities or research institutions.

4.1.1 What motivates scientists to be involved in science communication activities?

Unfortunately, there is scant literature that specifically analyzes Spanish scientists' motivation to participate in science communication activities. Martin Sempere et al. studied this issue among scientists based in Madrid. The authors concluded that scientists are motivated by a wish to improve public interest and enthusiasm for science, the public's scientific culture, and public awareness and appreciation of science and scientists (Martin-Sempere, Garzon-Garcia, and Rey-Rocha 2008). However, scientists may also be motivated by a sense of duty, especially in the case of senior researchers (The Royal Society 2006). Other studies suggest that the motivation is especially strong in the case of health science researchers, as they seek to promote medical science within the public sphere (Watermeyer 2012).

Dunwoody et al. and Besley et al. studied American scientists as public communicators. The primary motivation that scientists became involved in engagement activities were socials norms, a personal commitment to the public, good feelings of personal efficacy and professional obligation, and a desire to contribute to the public debate (Besley, Oh, and Nisbet 2013; Dunwoody, Brossard, and Dudo 2009). These findings indicate that researchers strongly believe that they should have a role in public debates. Bentley et al. studied the situation with climate change scientists and reported similar results especially when a substantial disjoint may exist between scientific findings and the impact they have on the public (Bentley et al. 2012). Nonetheless, Besley et al. showed that scientists from the United Kingdom specifically view policymakers as the most important group to engage with, rather than the general public (Besley and Nisbet 2013).

De Boer et al. also reported that Irish food safety experts have little confidence in the public's understanding of and ability to deal with scientific information and practices (De Boer et al. 2005). Other studies suggest that scientists engage with the public without reflecting on their own status as part of the public and act in accordance with their own linguistic and social domain (Cook, Pieri, and Robbins 2004). This context leads researchers to favor the deficit model: one-way communication activities designed to educate the public and defend science from misinformation (The Royal Society 2006). In contrast, scientists least prioritize communication that seeks to build trust and make the information imparted resonate with the public (Dudo et al. 2016).

Collins et al. studied scientists' usage of social media (Twitter, Facebook, LinkedIn or blogs) and concluded that researchers perceive numerous potential advantages to using social media in the workplace (Collins, Shiffman, and Rock 2016). However, most scientists consider social media to be useful to communicate with other scientists rather than suitable for science communication to the general public (Collins, Shiffman, and Rock 2016).

Torres Albero et al. studied the Spanish situation and concluded that a contrast exists between researchers' desire to disseminate knowledge and the limitations derived from a low degree of interest in science in broad sectors of the Spanish society, together with professional promotion policies that do not give priority to science communication activities. The authors coined the term "trapped in a golden cage" to characterize the situation of scientists in Spain, who see no need for public engagement because they perceive little public demand for it. This situation led Torres Albero et al. to conclude that Spanish scientists are "trapped between the need to engage in dissemination activities from a moral standpoint and a social and professional environment (lack of time and of academic recognition) that is hardly conducive to these activities" (Torres-Albero, Fernández-Esquinas, et al. 2011).

4.1.2 Why do scientists need to understand public perceptions?

As seen above, the traditional one-way approach to the science-society relationship still predominates in communication and outreach scenarios. However, many members of the public already understand basic scientific facts and concepts and therefore resist the presumption that they are not able to understand. Thus, "scientific education" alone may be insufficient for such citizens (Davies 2008a).

Sociodemographic factors such as gender, social background or ideology likely play a key role in how scientists view different dimensions of the public sphere (Besley and Nisbet 2013). These factors and others may also impact how scientists interact with the public and what they want to achieve by participating in these kinds of interactions (Besley and Nisbet 2013; Blok, Jensen, and Kaltoft 2008).

Some works reveal that scientists' perceptions of the public vary according to the scientists' experience (Besley and Nisbet 2013; Besley, Oh, and Nisbet 2013), field of research (Grand et al. 2015) and funding (Burningham et al. 2007). Greater experience in public engagement activities is associated with a better opinion of the public and with a more open-minded stance regarding how communication processes should be structured (e.g., dialogue or two-way communication rather than the idea of merely filling a knowledge vacuum) (Besley and Nisbet 2013). This range of perceptions entails that the term “public” is constructed in many different ways; indeed, it is important to consider “multiple publics.”

Some studies show that when scientists have closer contact with the lay public, they acquire a more nuanced view of this particular public and of the corresponding process of communication (Davies 2008a). Torres-Albero et al. described the average profile of Spanish scientists who are involved in disseminating scientific findings as males who are over the age of 40 and working in the highest professional category. Scientists who are not involved in public engagement activities, however, were also predominantly male but older (Torres-Albero, Fernández-Esquinas, et al. 2011). We have to take into account that this study was carried out in 2011 and that the profile of the typical scientist who participates in science communication in Spain may have changed since then. For example, early career researchers may have a key role in science communication as Donkor et al. reported in their studies with climate researchers from the United Kingdom and South Africa (Donkor et al. 2019). However, as far we know, there are no more recent studies addressing this issue in Spain.

4.1.3 Public surveys about science and technology

Several countries have launched studies to investigate the characteristics of the relation between science and society so that appropriate strategies for improving the effectiveness of scientific dissemination can be designed. One such example is the Pew Research Center report (Funk, Rainie, and Smith 2015), which focuses on a comparison of the views of the general public and scientists from the American Association for the Advancement of Science (AAAS). Another prominent example is the Science and Engineering Indicators report, last published in 2018 by the National Science Board of the United States; this biennial report provides a broad base of quantitative information about science, engineering, and technology, including public attitudes and understanding. In Europe, the European Commission regularly carries out opinion polls regarding science and technology (European Commission 2005, 2010b) and on specific topic such as biotechnologies (European Commission 2010a) or climate change (European Commission 2008). In Spain, every two years, the Spanish Foundation for Science and Technology (FECYT) analyzes the relationships between science, technology and society through a survey (FECYT 2017).

In these studies, the survey questions are usually designed following six key indicators included in the three main dimensions of scientific literacy described by John D. Miller in 1998: information, interest, knowledge, understanding, opinions and attitudes and confidence.

The biannual surveys of FECYT provide data on the public understanding of science in Spain (FECYT 2017) based on these indicators. However, there are no data on scientists' understanding of the perceptions of the public or of civil society organizations regarding scientists' role in the research, development and innovation process or on Spanish scientists' actual understanding of the public.

This gap supports the need for exploratory research to better understand the interaction between scientists and the public. If we want to promote public engagement and science dissemination, we need to understand researchers' views, opinions and attitudes towards the public. Therefore, the present study sought to answer the following research questions:

> RQ1. What are the opinions and attitudes of Spanish scientists towards the public?
>
> RQ2. What are the opinions and attitudes of Spanish scientists towards public engagement with science?
>
> RQ3. Are Spanish scientists' views in line with data available in Spain on the public's understanding of science?

4.2 Materials and methods

All the participants of this research were informed about the study and asked to sign a written consent. All of them were free to answer each one of the questions as well as to stop participating at any time.

The population studied consisted of researchers living and working in Spain participating in research and development projects funded by the Spanish Ministry of Science, Innovation and Universities during 2013 and 2014. Accordingly, we can ensure that people participating in the study have lived and worked in Spain for a certain period of time and that they have been involved in a research project funded by the Spanish government. Henceforth, we will call this population "Spanish scientists."

The study is focused on Spain due to the need for a better understanding of the reality in Spain, a country where scientific communication is very active but that nonetheless remains largely absent from the international literature on the topic.

To answer our research questions, the study was carried out in two phases: a first exploratory phase in which 14 semi-structured interviews were carried out with Spanish researchers to determine the scope of study and a second phase based on an online questionnaire completed by Spanish researchers.

The study was conducted as a collaborative process between the research team (the authors and 2 masters' students who only collaborate in data collection) and a working group composed of 14 representatives of Spanish Scientific Culture Units, which are structures formally recognized by the Spanish government and based at universities and research centers. These structures act as intermediaries between their host institutions and citizens with the main aim of promoting scientific, technological and innovation culture though different types of activities: scientific communication, outreach, training, etc. These units are key agents in the dissemination of science and innovation in Spain and provide a crucial service for improving and contributing to the training, culture and scientific knowledge of citizens (Capeáns, López, and Gonzalo 2012).

Table 9 summarizes the institutions that selected a representative as part of this working group:

University or research centre	City	Autonomous community
University of Seville	Seville	Andalusia
University of Zaragoza	Zaragoza	Aragon
National Research Centre on Human Evolution (CENIEH)	Burgos	Castile and León
University Jaume I	Castellón de la Plana	Community of Valencia
Polytechnic University of Madrid	Madrid	Madrid
University Carlos III	Madrid	Madrid
University of Cordoba	Córdoba	Andalusia
International University of La Rioja	Logroño	La Rioja
Seneca Foundation	Murcia	Murcia
University of the Basque Country	Leioa-Bizkaia	Basque Country
AZTI-Tecnalia	Pasaia, Guipuzkoa	Basque Country
Institute for Bioengineering of Catalonia	Barcelona	Catalonia
Open University of Catalonia	Barcelona	Catalonia
Pompeu Fabra University	Barcelona	Catalonia

Table 9. Working group institutions.

The working group collaborated with the research team throughout the study in several key points: definition of the study dimensions, revision of the script of the semi structured interviews, determining the survey design and the sample selection. We also relied on the experience of the working group during the discussion of the results to ensure the reliability of the interpretations. The units of scientific culture were selected taking into account the geographical distribution of the researchers in the country.

4.2.1 Scope of study

To map the different views, define the scope of the study, and devise the specific questions to be included in the online survey, we conducted 14 semi-structured interviews. The main objective of these interviews was the qualitative exploration of scientists' views on different subjects related to our research questions, such as the public interest in science and technology, the public perception of scientists' profession, the public image of science and technology, the scientific cultural level of citizens, how the public is informed about science, and their role in public engagement activities.

The specific script of the semi-structured interview was prepared following the guidelines of Martín Izard (2010) and was devised jointly by the abovementioned working group and the research team. Before participating, representatives were informed about the study and asked to sign a written consent form. The research team developed a semi-structured interview protocol and two interviewers conducted face to face or Skype interviews. All the interviews were recorded, transcribed immediately, and shared with the research team. For reasons of privacy protection, the names of the representatives and the organizations have been anonymized. Feedback was also obtained from the working group associated with the project. One researcher from each unit's institution was interviewed during the spring of 2016.

We interviewed seven men and seven women. In choosing the sample, we took into account research experience (over or under 10 years working in research), the degree of involvement in public engagement activities (participating in more than or fewer than 3 activities per year) and the research field. Each member of the Spanish Scientific Culture Units included in our working group suggested one researcher from their university or research center according to the selection criteria noted above. Finally, we included researchers from the fields of biology, engineering, paleontology, veterinary science, physics, mathematics and chemistry to gather a diversity of views. Researchers from social sciences and humanities were not included, but the research team decided that the variety of disciplines was wide enough to perform this exploratory study.

Based on these semi-structured interviews and our research questions, the study explores the following themes:

- *Scientists' opinions of and attitudes towards the public*: How scientists perceive public interest in science and technology, how scientists view public understanding of science and technology, and the public image and perception of scientists and the profession. In this section, we also analyze how scientists believe the public is informed about science and technology-related issues (RQ1 and 2).
- *Scientists' opinions of and attitudes towards their role in public engagement activities*: How scientists should be involved in science dissemination (RQ3).

4.2.2 Survey design

The specific questions of the survey were developed in close consultation with the working group. The survey design incorporated the key indicators and certain questions used in surveys on public understanding of science, such as those carried out every two years by the FECYT (2017) or the Science and Engineering Indicators report, published by the National Science Board (2018) of the United States, in order to be able to compare the answers. The survey also included new questions to provide a broader knowledge as well as certain sociodemographic questions.

The exact wording and complete questionnaire are available in S1 Questionnaire. Specifically, questions 2, 3, 5, 6 and 8 of the questionnaire are inspired by the public perception surveys of the FECYT (2017). Of these questions, questions 3, 5 and 6 are the same questions that the FECYT used in their survey. Of course, the wording has been changed since the FECYT study focuses on the responses of society, whereas our study focuses on the responses of researchers. Question 4 is inspired by a question from the Science and Engineering Indicators report. Similarly, readjustments were made in the wording due to the difference in the target audience in the two studies. Questions 1, 7, 9 and 10 were defined by the research group taking into account the scope of the study and researchers' responses in the exploratory interviews.

The final online questionnaire consisted of nine questions about researchers' perceptions of society, seven of which were multiple-choice questions in which the researchers had to select the option that best suited their opinion. In the other two questions, the scientists were asked to indicate their degree of agreement based on a Likert scale. In addition, a tenth multiple-choice question asked the researchers which professionals should be involved in science dissemination. The questionnaire was accompanied by an informative e-mail specifying the purpose of the study and the use that was to be made with the data that the participants provided. Respondents were free to choose whether or not to answer any particular question. Before submitting their answers, respondents had to check that they have received informed consent. The average survey duration was approximately 15 minutes.

4.2.3 Survey sampling

According to data from the Statistics Institute of the Spanish Government (Instituto Nacional de Estadística 2014), the number of Spanish researchers dedicated to research and development was 122,235, a figure representing the maximum size of the study population. We did not take into account scientists working in commercial companies, who, according to the Statistics Institute, number approximately 45,000 people in Spain (FECYT 2017). Thus, the study inferences concern scientists working in public universities or research centers.

Adhering to the tailored design method (Dillman et al. 2009), each member of the working group made three contacts with members of the sample of their institution over approximately four weeks and sent e-mail reminders once responses from the first invited contact had been received. Finally, the online survey was distributed to 5554 scientists from the working group institutions. The response rate was 22%, resulting in a final data set of 1022 scientists (sampling margin of error of approximately 3% and a 95% confidence level). The response rate to online questionnaires is usually relatively low, but this response rate is consistent with those reported for other online surveys of expert communities (e.g., Dudo et al. 2016). Moreover, this is a descriptive study that does not seek to analyze precise differences between participants but, rather, to provide a group description. The online survey was sent during the autumn of 2016.

The data were weighted to ensure that the demographics of the sample reflected the underlying population of scientists; that is, we have taken into account factors such as gender (60% male and 40% female), age, research experience, and field of study (see Table 10). The field division used is the one provided by the Spanish Ministry of Science, Innovation and Universities.

Age group	N	% of the sample
Under 24 years old	42	4
25 to 34 years old	257	25
35 to 44 years old	274	27
45 to 54 years	280	27
55 to 64 years old	139	14
Over 65 years old	30	3

Level of experience	N	% of the sample
1 to 10 years	335	33
11 to 20 years	268	26
21 to 30 years	279	27
31 to 40 years	112	11
Over 41 years	28	3

Field of study	N	% of the sample
Exact and natural sciences	374	37
Engineering and technology	241	24
Medical sciences	228	22
Agricultural sciences	37	4
Social sciences	108	11
Humanities	34	3

Table 10. Age, research experience and field of study.

To study the relationships between the different variables, we performed Pearson's chi-squared test with the statistical software Statistical Package for the Social Sciences (SPSS), version 23.

4.3 Results

4.3.1 Scientists' views of public interest in science and technology

As we noted in previous sections, the question regarding public interest in science and technology was defined by the research team taking into account the researchers' responses in the exploratory interviews and questions on the same topic proposed in the FECYT study (2017).

During these interviews, the answers included in Table 11 were mentioned enough times (in more than 7 interviews) to be considered as an item for study. The wording of answer 4 "No, Spanish society has no interest in knowing more about science and technology" derives from the idea that, usually, when one is interested in something, one wants to "know more" about the subject. This same action of "wanting to know more" appears in the FECYT studies noted above related to society's interest in science and technology issues (FECYT 2017). Approximately 73% of the scientists surveyed considered that Spanish society is interested in science and technology issues (Table 11).

Do you consider that Spanish society is interested in knowing more about scientific and technological issues?			
	Female	**Male**	**Total**
Yes, Spanish society is interested in science and technology	11.5%	15.1%	13.7%
Yes, Spanish society is interested only in health, food and applied science	35.6%	28.3%	31.2%
Yes, Spanish society is interested in science and technology but has a lack of understanding	29.7%	27.0%	28.1%
No, Spanish society has no interest in knowing more about science and technology	23.1%	29.5%	26.9%

Table 11. Scientists' views of public interest in science and technology (total and according to gender).

However, more than one-third think considered the interest is only related to applied science or specific topics, such as health or nutrition. Women support this view more strongly than men (36% vs. 28%, $p = 0.001$). Additionally, 28% of the sample asserted that despite being interested in this field, the public has a lack of understanding of science and technology. The percentage of women supporting this view is also slightly higher than that of men (30% vs. 27%, $p = 0.001$).

The view that the public has no interest in science and technology was slightly more common in men than in women (30% vs. 23%, $p = 0.001$). There were also differences by field of study: those working in the engineering and technology fields (33%) were less confident about public interest in science and technology than were scientists in the other groups ($p = 0.001$). Scientists working in the humanities showed more positive views (38%), especially regarding public interest in applied science ($p = 0.001$).

4.3.2 Scientists' views about the public image of science and technology as a priority

One of the most classic indicators of the degree of commitment of citizens to science is whether they consider public spending in this area a priority. The answers of scientists to the corresponding question are listed in Table 12.

Do you think that public funding for science and technology is a priority for Spanish society?	
Yes, Spanish society considers public investment in science and technology to be a priority	8%
Yes, but public investment is accepted more in applied science than in basic science	35%
No, Spanish society does not consider public investment in science and technology to be a priority	57%

Table 12. Scientists' views on the public prioritization of public investment in science and technology.

Of the sample, 57% agreed that Spanish society does not consider public investment in science and technology to be a priority. This view was more commonly supported by male than by female respondents (61% vs. 53%, $p = 0.002$). Over a third of the respondents indicated that society accepts this type of investment more readily in applied science than in basic science. In this case, female respondents were slightly more positive than males (41% vs. 31%, $p = 0.002$).

4.3.3 Scientists' views of the public knowledge and understanding of science and technology issues

As shown in Table 13, with respect to the cultural level of Spanish society in terms of science and technology compared with that in other European countries, most of the sample (75%) reported that it is low or very low, with only 1% viewing it as high or very high. There were no statistically significant differences by gender, experience or research fields.

What would you say is the level of scientific culture in Spain compared to other countries in the European Union?	
Very low	17.5%
Low	57.8%
Normal	23.3%
High	1.3%
Very high	0.1%

Table 13. Scientists' views of the level of scientific culture in Spain.

Table 14 summarizes scientists' answers to a question on the capacity of citizens to correctly choose the best way to test the effectiveness of a treatment against high blood pressure. Most of the scientists surveyed think that a quarter of Spanish society could answer this question correctly, whereas 21% of them consider that Spanish society is not capable of answering this question correctly. This opinion was shared more widely among men than women (24% vs. 17%, $p = 0.037$). As the age and research experience of the scientists surveyed increased, the confidence in Spanish society's ability to respond to questions of this kind decreased (16%, 17%, 26%, 27% and 36%, $p = 0.019$).

Some questionnaires regarding public perception of science include questions such as these:	
Imagine that two scientists want to know whether a given substance is effective against hypertension: • **Scientist A proposes studying 1000 people with hypertension by giving the substance to all of them and observing how many people experience a decrease in their blood pressure.** • **Scientist B proposes studying 1000 people with hypertension but giving the substance to only 500 people (leaving the other 500 to follow their usual treatment) and observing how many individuals in each group experience a decrease in their blood pressure.** **Which of the two scientists proposes the best way to test the drug?**	
Do you consider that society is able to answer this question correctly?	
Less than a quarter of Spanish society can answer this question correctly.	21%
A quarter of Spanish society could answer this question correctly.	55%
Half of Spanish society could answer this question correctly.	22%
More than half of Spanish society could answer this question correctly.	2%

Table 14. Scientists' views of public understanding of a scientific process (role of a clinical trial).

4.3.4 Scientists' views of the public perception of scientists and their profession

We replicated a question devised by the FECYT by asking scientists to indicate how Spanish society values 11 different professions on a scale of 1 (poorly valued) to 5 (highly valued). As we can see in Figure 7, Spanish scientists believe that athletes are the professional group valued the highest by the public and politicians the group valued the least. Spanish scientists also consider that scientists are less highly valued than doctors, engineers, judges, businesspeople and lawyers, with scientists ranked in seventh position. There were no statistically significant differences by age, gender, experience or research fields.

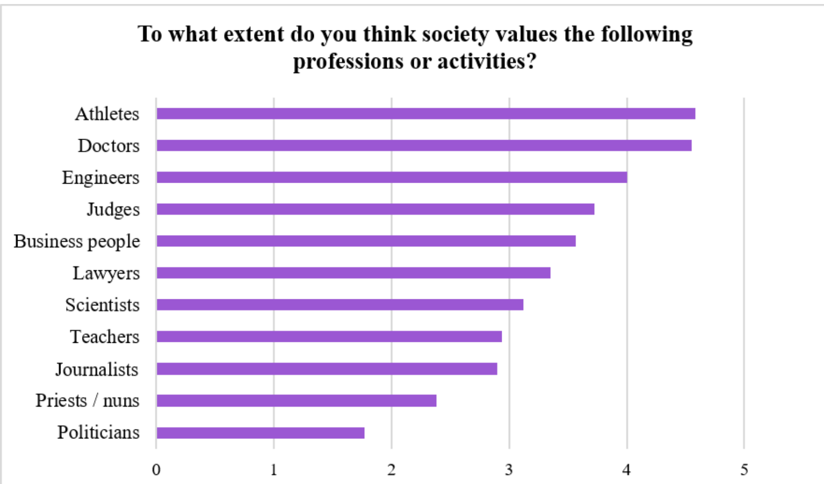


Figure 7. Scientists' views of public valuing of professions.

To gain further knowledge about scientists' perceptions of the public recognition of their profession, we asked them to select the opinions that were most closely aligned with their own opinions from a list of options derived from FECYT surveys. The exact wording and responses are shown in Table 15. Most answers reflect scientists' perception that their job is not valued enough by the public.

Mark the statement that best fits your opinion	
Spanish society feels that research is a male-oriented profession.	14%
Spanish society believes that research is an underpaid profession.	37%
Spanish society sees research as a profession lacking in job stability.	46%
Research is useful to Spanish society, but the public does not consider it to be a priority.	88%
Spanish society does not see research as a profession that is useful to society.	18%

Table 15. Scientists' views of the public perception of issues related to scientists.

Other facets of the same perception can be seen in Table 16. Notably, only 3% of respondents considered that "society has a real image of the actual work of the researcher," while the option "society has a stereotypical image of the researcher" was chosen by 79% of respondents. The latter view was held by 85% of researchers from the fields of exact and natural sciences, by 80% of those in engineering and technology, but only by 31% of scientists from the humanities.

Mark the statement that best fits your opinion	
Spanish society respects and values scientists as pillars of modern society.	12%
Spanish society considers that scientists are a social point of reference, but only in their respective fields.	60%
Spanish society has a stereotypical image of researchers as mad scientists, eccentric, very clever, capable of solving anything but disconnected from real life.	79%
Spanish society has a realistic perception of the actual work of researchers' routines, i.e., reading and writing scientific articles, looking for funding, etc.	3%

Table 16. Scientists' views of the public perception of scientists.

4.3.5 Scientists' views of how the public is informed about science and technology

Asked about "how society is informed about science and technology," the majority of scientists selected the press and TV (see Figure 8).

Less experienced scientists (fewer than 20 years in research) and the most experienced scientists (more than 40 years in research) tended to consider TV as a less important channel for information. If scientists' views are correct on the less commonly used means of information, there is a high potential to increase the use of informative activities, books, and institutional channels.

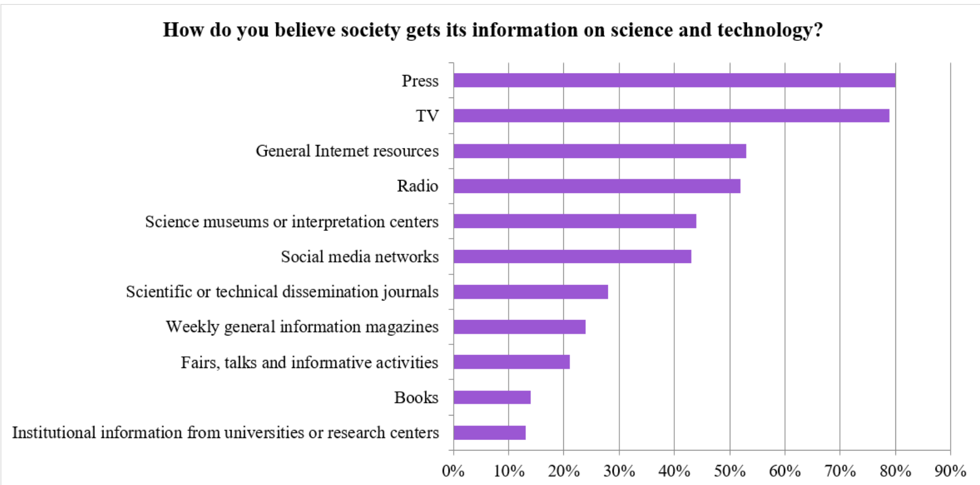


Figure 8. Scientists' views of how the public is informed about science and technology

4.3.6 Scientists' views of their role in public engagement activities

We also assessed who scientists thought should be involved in science communication and public engagement activities. They could choose more than one option from the list shown in Table 17. Their answers suggest there is broad potential to strengthen collaborations among researchers and communication specialists. There were no statistically significant differences by gender, age, experience or research fields.

In your opinion, who should communicate or disseminate science and technology?	
Research staff	69%
Specialized communication staff linked to the research center or university	87%
Journalists or specialized communicators	74%
No one	1%

Table 17. Scientists' views of who has to communicate or disseminate science and technology.

Moreover, there was a clear inverse relationship between scientists' age and having received some training in science communication (Figure 9) (p for trend <0.001).

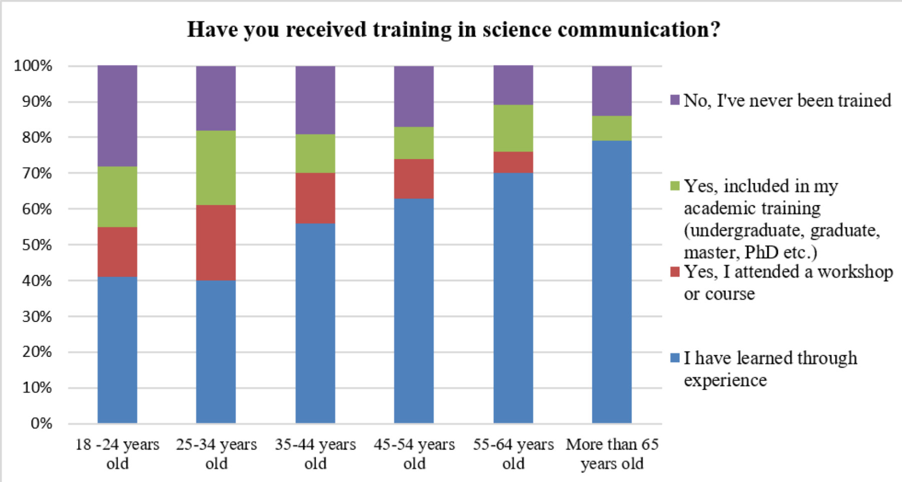


Figure 9. Training in scientific communication.

4.4 Discussion

The results show that Spanish scientists think that the general public has a serious lack of knowledge and understanding of scientific reasoning, although researchers recognize that science interests the public. Researchers also believe that the public's valuation of the scientific profession is low and that the press is the most widely used source of information. Spanish scientists consider communication and dissemination of science to be a shared responsibility among research staff, institutional communicators and scientific journalists.

There is broad potential to strengthen collaborations among researchers and communication specialists, for example, by funding programs for science communication activities, through awards for science journalism, formal recognition of communication activities in the scientists' curriculum', etc. The clear increase in training in science communication of younger researchers further supports the possibilities of current efforts to educate researchers in science communication.

As we reported in previous sections, Spanish scientists have a quite positive perception (73%) of the level of public interest in science and technology. The last survey of the FECYT (2017) shows a slight increase in the degree of interest in science of 7% from the 2008 survey), although interest is still low. Similar data were also reported by the Eurobarometer survey "Scientific research in the media": only 23% of the surveyed Spaniards showed interest in scientific research, placing this topic in fourth place, while in other countries such as Sweden, Greece, France, Belgium, Cyprus and Luxembourg, it is ranked in first place (Revuelta 2014). Thus, Spanish scientists have a more positive perception of the level of public interest than those observed in other public surveys (see Figure 10).

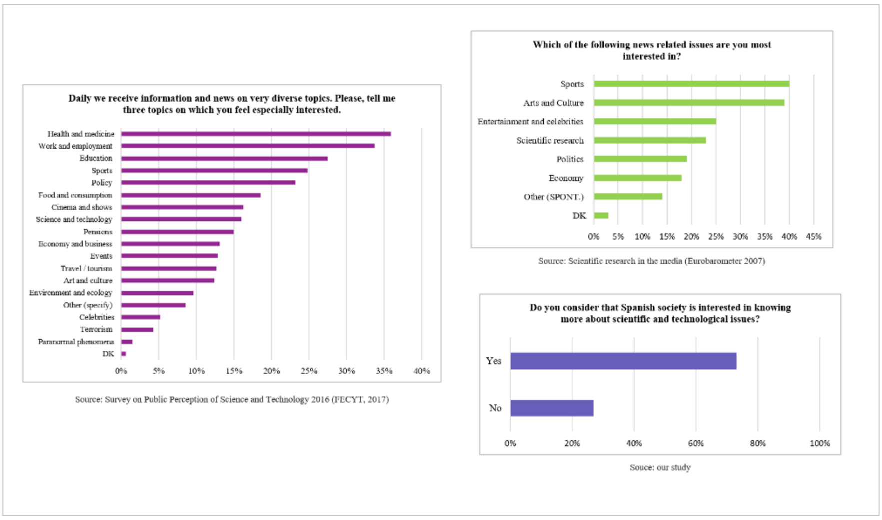


Figure 10. The perceived level of interest in science and technology by society in general (FECYT and Eurobarometer data) and scientists (our data).

The last FECYT report concluded that the areas in which citizens would increase public spending were mainly health and education, while science and technology were ranked in sixth place (FECYT 2017). This report also shows that 53% of the surveyed Spaniards believe that the level of commitment of the Spanish government to research is insufficient.

However, other factors to be taken into account are the economic situation of Spain in the last few years and how the recession influenced priorities in public spending to cover other social needs. As we have seen, 57% of the surveyed scientists agreed that Spanish society does not consider public investment in science and technology to be a priority. With this in mind, our results suggest that scientists' views of this issue are more negative than those of the rest of society (see Figure 11).

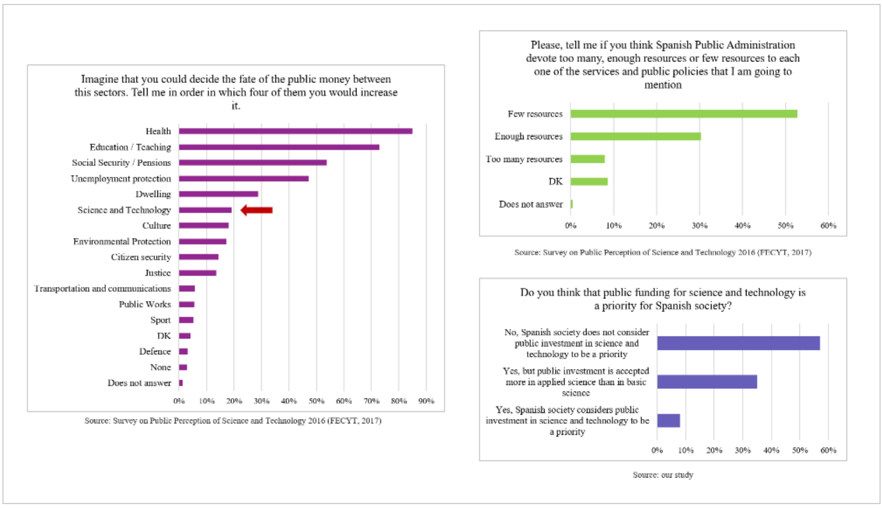


Figure 11. Prioritization of public spending in science and technology by society in general (FECYT data) and scientists (our data).

The view of the public as uninterested and incapable of understanding scientific research was also reported by Besley and Nisbet (2013). Our impression is that this perception leads scientists to think that society does not have the necessary skills to understand how important public investment in science and technology truly is.

We note a concept that commonly appears in the researchers' responses: scientists tend to consider the public to be much more knowledgeable and sensitive in relation to scientific issues that affect them directly.

In general, Spanish scientists think that the public has a lack of scientific culture. Comparing these results with those provided by the FECYT (2017) shows that the view of scientists is clearly less positive than the public's self-view (see Figure 12). As we can see in Figure 12, the majority of the surveyed scientists agreed that Spanish society has a low (option chosen by 58% of scientists) or very low (18%) level of scientific culture. In contrast, the results of the FECYT study (2017) show that most members of the Spanish society consider their own level of scientific culture to be normal (42%), or lower (31%) than the level of other European countries .

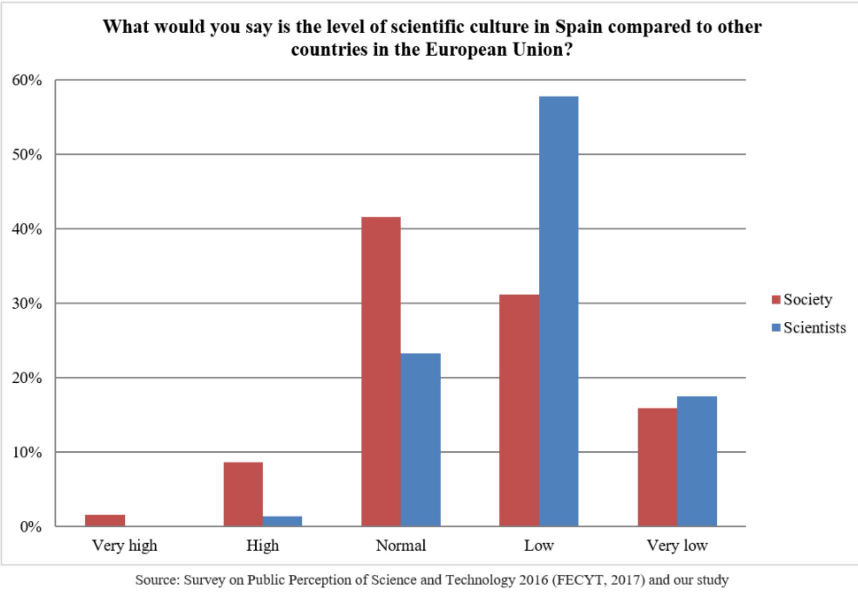


Figure 12. The perceived level of scientific culture in Spain compared to other European countries by society in general (FECYT data) and scientists (our data).

Some studies of scientists' views of the public showed that the most widespread view among researchers is that the main barrier to a greater understanding of science among the public is a lack of science education (Besley and Nisbet 2013). This is also in line with the traditional deficit model of science communication that sees scientific illiteracy as the key problem (Davies 2008a).

In our study, some scientists pointed out that the lack of knowledge of science does not contradict or interfere with public interest in knowing more about science and technology. This position goes beyond the deficit model, which attributes public skepticism or hostility to science and technology to a lack of understanding resulting from a lack of information.

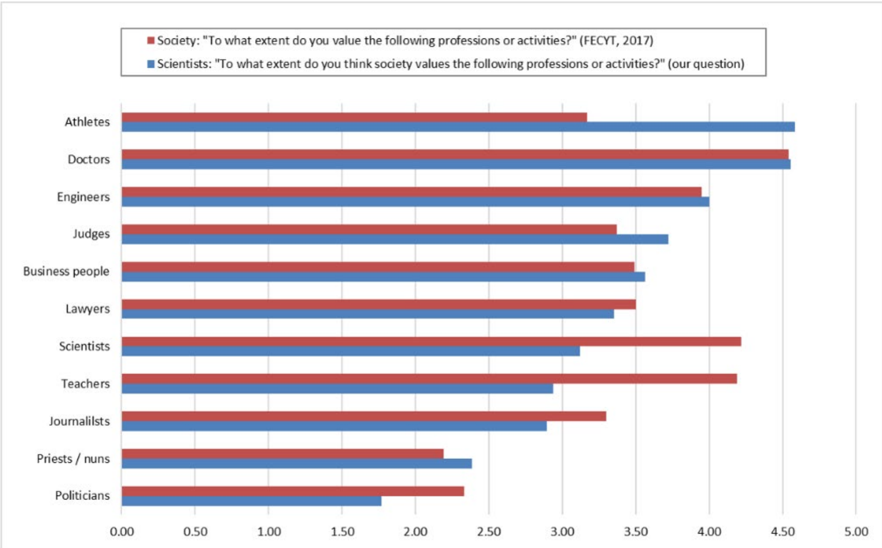
Understanding how clinical trials work implies a knowledge of the nature of science and key elements such as the need for control or replication to validate a study. However, the results from the present study suggest that scientists, especially men, feel that most of the Spanish population does not have the capacity to understand specific scientific knowledge, such as clinical trials. The Science and Engineering Indicators report published by the National Science Board (2018) offers results regarding the same question on public understanding of scientific experiments similar to the views of Spanish scientists.

The exact same question was not answered by Spanish society, but the last FECYT survey (Fundación Española para la Ciencia y la Tecnología (FECYT) 2017) included a different question regarding clinical trials with several answers to choose from, where the majority of the population did not know the scientific procedures, which is also in line with the scientists' predictions in our survey. Of course, more studies are needed on the degree of understanding of Spanish society on different scientific concepts to understand the reality of the situation. However, the main finding is that Spanish scientists consider that the majority of Spanish society is not able to understand key aspects of the scientific process.

Older researchers, who are not as involved in public engagement activities as younger ones, have a more traditional view of the public (Davies 2008a) based on the deficit model. Such results are consistent with the typical Spanish scientists involved in dissemination activities described by Torres-Albero, et al. (2011). Moreover, our study also shows that younger scientists tend to have more formal training in science communication than their older colleagues. Therefore, training in communication or public engagement could be beneficial for improving scientists' perceptions of the public since it could ensure a more realistic understanding of who the public are and what the public want.

Comparing our results with those from the last FECYT report (see Figure 13), we can see that Spanish society values scientific professions more than researchers believe (FECYT 2017).

Moreover, studies on changes in the public recognition of professions indicate a growing level of recognition of doctors, scientists and teachers and, most recently, of engineers (FECYT 2017). Thus, Spanish society ranks all professions related to science and technology (doctors, scientists and engineers) among the most highly valued groups.



Source: Survey on Public Perception of Science and Technology 2016 (FECYT, 2017) and our study

Figure 13. The perceived level of public recognition of professions by society in general (FECYT 2016 data) and by scientists (our data).

It appears that in Spanish society, the scientific profession enjoys a high level of recognition, yet some studies suggest that scientists do not believe so (Revuelta 2018). Other studies related scientists' view to a concern about being identified as a potential target of criticism; they also related such a view with the belief that the public would misunderstand any attempt at communication and either make the scientists look bad or misuse their work (Davies 2008a).

These views could be related to those reported by scientists in our survey, where scientists consider that society does not have a true image of researchers because the public is not familiar with their profession. These views were especially supported by researchers in the field of exact and natural sciences, which is perhaps the field of study with the least amount of direct contact with society. Despite this perception, scientists also believe that society considers them as a point of reference in their respective fields.

However, as we can see in Figure 14, the press is seen by scientists as the most widely used source of information, while considerably less than half of society actually considers this (Fundación Española para la Ciencia y la Tecnología (FECYT) 2017) to be the case. This perception could be due to the great importance that universities and research centers give to press clippings as a measure of their impact in mass media.

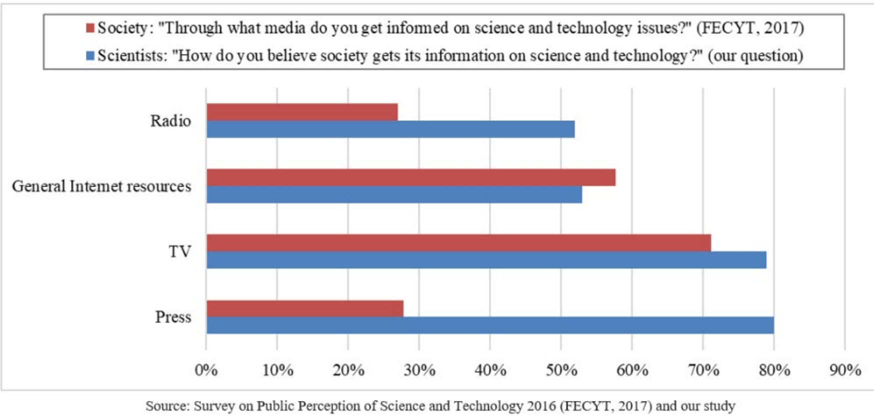


Figure 14. The perceived main sources of science and technology information by society (FECYT 2016 data) and by scientists (our data).

The data show that scientists consider that scientific communication is a shared responsibility among the institutional communication departments, journalists and researchers. A higher proportion of scientists in our survey considered that the communication and dissemination of science were the responsibility of other specialists rather than of researchers. However, some studies have observed that the public places a high value on the participation of scientists in this kind of activity normative (Ecklund, James, and Lincoln 2012). We must also bear in mind that in Spain, participation in public engagement activities is virtually always voluntary and that scientists involved seldom receive formal recognition for this work. Our findings suggest that scientists' efforts could be better recognized institutionally and academically, and perhaps also socially; this would not only legitimize public engagement efforts but also make them normative (Ecklund, James, and Lincoln 2012).

4.5 Conclusions

Overall, our findings provide an overview of Spanish scientists' opinions and attitudes towards citizen's understanding of science and on scientists' own role in public engagement activities. The findings thus enable us to identify the differences and to propose strategies to improve citizen participation in the research process.

4.5.1 Opinions and attitudes of Spanish scientists towards the public

Many scientists in Spain still believe that the lack of public scientific knowledge is the key hindrance to society being involved in public engagement activities. This belief fits better with a one-way communication approach than with approaches focusing on mutual learning processes or public engagement activities.

However, it is the latter approach that is currently being promoted by many institutions and organizations worldwide, including Spain. Knowing what Spanish scientists think about the public is key to promoting rapprochement between the scientific community and society. On the one hand, we believe that it is necessary to increase researchers' knowledge of public perception of science and technology. A good option to do this would be through training programs included in formal scientific education (undergraduate degrees, master's and doctoral programs).

On the other hand, if the science and technology system truly wants to encourage the involvement of researchers in public engagement activities in science, these types of actions should be formally recognized for career promotion.

4.5.2 Opinions and attitudes of Spanish scientists towards public engagement in science

Scientists consider public engagement activities to be a shared responsibility among institutional communication departments, journalists and researchers. The advantage of this situation is that

Spanish scientists have a willingness to participate in scientific communication activities. In addition, they consider that scientific communication is a multidisciplinary activity involving collaboration among different actors.

Despite this, we have seen that scientists' confidence in public capacities decreased with increasing age. This finding is more related to the deficit model approach described above than to participatory activities such as public engagement. However, other studies have reported that a greater contact with science communication and experience in outreach activities improves views on public abilities and capacities (Davies 2008a). Therefore, it is plausible that these findings are explained by a relative lack of experience in such activities by the oldest cohorts of scientists; this process also seems likely in countries other than Spain. Therefore, we believe that promoting mutual learning and public engagement activities by the scientific institutions and funding agencies is crucial to improve this situation.

We also observed that younger generations tended to receive more specialized training in scientific communication. Our hypothesis is that including formal training in science communication and public understanding of science during a scientist's research career could foster a more realistic view of the public and help to boost public engagement. Obviously, more research must be carried out to better assess this issue.

4.5.3 Differences between Spanish scientists' views and public understanding of science

There are some differences between the perceptions of scientists analyzed here and the perceptions of the public collected in the biannual reports of the FECYT (2017). Specifically, these differences relate to the sources of information used by the public, the level of public recognition that science and researchers receive, the level of scientific education and the level of interest in science and technology.

Identifying these differences in perceptions is important to propose strategies that improve the relationship between the scientific community and society. For example, if scientists know what sources of information the public uses the most, they are probably more willing to participate in scientific communication activities that may have an impact on these channels. Similarly, awareness of the level of social valuation that their profession has can influence the scientists' perception of the public. This may also favor the willingness among scientists to participate in public engagement activities.

The challenge for the future is to explore how to close such gaps in perceptions so that scientists can have a better understanding of the public and its interests and carry out public engagement activities efficiently. Through these kinds of activities, scientists can enter into discussions with a wide range of stakeholders, allowing questions and concerns to be better understood and addressed. By doing so, scientists can connect different points of view, change aspects of their work, and make it more relevant to society.

CHAPTER 5. SOCIAL PARTICIPATION IN SCIENCE: PERSPECTIVES OF THE SPANISH CIVIL SOCIETY ORGANIZATIONS

Manuscript:

Llorente, C. Revuelta, G. Carrió, M.
Accepted in Public Understanding of Science

Abstract:

There is a general trend towards the more active, broader and more inclusive participation of different stakeholders in science. The civil society organizations (CSOs) inclusion in scientific process is being promoted, however there are few approaches to understand CSO roles in research. This study is based on the analysis of 31 semi-structured interviews with Spanish CSO managers and representatives.

Our main results regarding the current relationship between CSOs and the research system are: A) CSOs mainly participate in science within one single research moment and they are unaware of their potential. B) Lack of resources, mutual knowledge (among CSOs and Academia) and capabilities are the identified barriers for CSOs' participation. C) There is a need to strengthen links between CSOs and research by training in collaborative methodologies and communication skills, promoting participatory research, increasing mutual understanding about the research system and the third sector, and aligning research and CSOs' objectives.

Keywords: Participation and science governance, Public engagement with science and technology, Social inclusion, Co-responsibility

5.1 Introduction

Over the past 20 years, new spaces related to science and innovation have been established, which has promoted the inclusion of members of the general public. The debate about the relationship between science and society gives importance to the concept of the "democratization of science", which is closely related to the idea of “co-responsibility” on which the concept labelled “responsible research and innovation” (RRI) is based (Stilgoe, Owen, and Macnaghten 2013).

There is a general trend towards the more active, broader and more inclusive participation of different stakeholders in scientific-technical projects in a wide variety of research and coordination activities throughout the world (Hockfield 2018; Mejlgaard et al. 2018). For example, the quadruple helix model of innovation recognizes society as one of the actors in the innovation system (Schütz, Heidingsfelder, and Schraudner 2019), together with science, policy and industry. Similarly, the growing “open science” concept can be understood as “transparent and accessible knowledge that is shared and developed through collaborative networks” (Vicente-Saez and Martinez-Fuentes 2018). The inclusion of greater public involvement in research and innovation processes has also been promoted by the European Commission program Horizon 2020 (2014) and the governments of many countries, such as those of Australia (Halpin 2012), Latin American countries (A. Smith, Fressoli, and Thomas 2014), and India (Chakraborty and Giuffredi 2020).

In this sense, the public attitude towards science and technology seems to have affected science-related areas of public policies, such as those pertaining to global warming, the prices of antiviral drugs in developing countries, wireless smart meters or the trade of genetically modified organisms (Buiatti, Christou, and Pastore 2013; Doh and Guay 2006; Hess and Coley 2012). During the last decade, some social opinions on scientific and technological issues have shaped decision making regarding scientific policies, for example, in the case of genetically modified food (Berg and Lidskog 2018). Another example is the phenomena of Greta Thunberg and Fridays for Future, which has prompted unprecedented numbers of youth to join the climate movement around the world (Fisher 2019). This influence is important beyond its potential impact on climate policy because it is creating a cohort of citizens who will be active participants in democracy (Fisher 2019).

All these social-inclusion trends hold that the responsibility in science and innovation is shared and that scientists, researchers' funders, innovators and other societal actors have a collective responsibility in science governance and scientific knowledge production (Stilgoe, Owen, and Macnaghten 2013). René von Schomberg also suggested that the condition of co-responsibility provides the ground of responsiveness among and between actors in research (Von Schomberg 2011). Thus co-responsibility implies explicit commitments and mutual obligations of all actors (Stilgoe, Owen, and Macnaghten 2013) and can only be reached with broader stakeholder engagement in technical and scientific projects (Hockfield 2018; Mejlgaard et al. 2018).

All society-science relationships encompass any form of active non-scientists participation (individual citizens, non-governmental organizations, groups of patients, etc.) in the process of research to generate science-based knowledge, from setting the research agenda (Rowe and Frewer 2004) by asking research questions, to collecting data, analysing the results and/or contribute to decision making (Bonney et al. 2009; Lewenstein 2004; Lidskog 2008). The diversity of these participative practices might be classified along a spectrum from minimal engagement of citizens to a total commitment as proposed in Arnsteins' leader of participation (1969). Thus, social participation in science can be found from participating in crowd-sourcing programs for collecting data to co-construction of knowledge and of research questions through deliberative processes (Haklay 2013; Schrögel and Kolleck 2018).

5.1.1 Civil society organizations as key stakeholders for public engagement

The inclusion of stakeholder groups in research processes improves the feeling of belonging to the research by all the members (Calder 2002). An example of this is Bernauer and Gampfer's study, which reported that the popular legitimacy of global climate governance decreases when civil society is excluded and increases when civil society is added (Bernauer and Gampfer 2013).

Similar results were reported by Doh and Guay (2006) regarding environmental institutions in Europe and the United States combining the activism of non-governmental organizations (NGOs) with their corporate strategies to meet their social responsibilities. According to Frickel *et al.* (2010), these types of strategies can place in the spotlight the "undone sciences" which are investigations that civil society organizations (CSOs) identify as being worrying or worthy of attention but are not being carried out. Indeed, the greatest challenge of this type of initiative lies in developing collective and integrated knowledge among scientists and the other stakeholders included in the research process (Cornell et al. 2013; Jacobi et al. 2017).

Civil society organizations (CSOs) can act as platforms that collect social opinions and as speakers of society's concerns. According to stakeholder theory (Hojnacki 1999), CSOs can develop power, urgency, and legitimacy. This suggests that CSOs are important actors who can realize the promise of participative research and be responsive to the real world (Smismans 2008). The active participation of members from different sectors and with different forms of knowledge in finding the solution to a given problem helps to promote the vision of a shared future (Jacobi et al. 2017), as well as a better understanding of scientific and technological processes (Stilgoe, Lock, and Wilsdon 2014) and the fulfilment of the reported will of society to acquire more responsibility in decision making (Rogers 2006).

CSOs are seen as "alliance-brokers between public and policymakers" (Mercer and Green 2013), which implies that these organizations may be able to take advantage of their position to influence the resolution of public policy issues, including those related to science and technology (Rainey, Wakunuma, and Stahl 2017).

This ability to participate in agenda setting at the policy level is reflected in the idea that CSOs' expertise should be included at the research project level (European Science Foundation 2013), not only to fulfil the CSOs' traditional dissemination role to the public and societal groups (Mercer and Green 2013) but also to obtain the sectoral knowledge and oversight that CSOs can provide in research (Ahrweiler et al. 2019; Bernauer and Gampfer 2013). Moreover, by establishing scientific dialogues that unite scientists with social actors as representatives of companies, NGOs and politicians offer the opportunity to understand and jointly analyse global problems and make decisions accordingly (Malyska, Bolla, and Twardowski 2016; Welp et al. 2006).

There have been numerous attempts to stimulate participation in research and to embed participative processes in research governance

(European Commission, 2014). Despite being central to the co-responsibility approach, the term "civil society organization" is not well defined (Ahrweiler et al. 2019; Rainey, Wakunuma, and Stahl 2017). Terms such as "voluntary", "third sector", "charities", and "non-governmental organizations" have overlapping characteristics and may be regarded as CSOs (Nugroho 2011).

Furthermore, there is no consensus on the specific roles that CSOs should perform in science and technology research (Steen-Johnsen, Eynaud, and Wijkström 2011). However, it has been reported that the role of CSOs in research and innovation projects is much more multifaceted (data providers, providers of access to the research field, providers of specific domain expertise, etc.) than is currently assumed (Ahrweiler et al. 2019).

On the other hand, some authors have questioned the importance of CSOs in research and innovation systems. For example, Krabbenborg and Mulder (2015) considered the role of CSOs as that of an early warning sign of potential risks and that this role of "scientists' opponents" and "nego-technology developers" may be problematic in open early-stage debates. De Saille (2015) calls attention to power imbalances among CSOs. Similarly, Taminiau (2006) and Elzen *et al.*, (2011) alluded that CSOs do not have much influence on their own. Rather, they are only influential when they are aligned with other actors such as policy-makers, companies or regulators (Elzen et al. 2011).

Nevertheless, given the high potential that CSOs may have in research, it is necessary to determine the current situation between these organizations and the science and technology system to make future recommendations for encouraging the effective participation of such organizations.

5.1.2 The Spanish third sector at a glance

The third sector can be understood as the set of "organizations which are not part of the traditional private sector nor of the public sector" (Defourny 2013). In Spain, this mostly includes social cooperatives, charities, mutual societies, associations, foundations and other labor-oriented enterprises (Monzón and Chaves, 2012). The other two major terms used in Spain to refer to those entities have been "nonprofit organizations" (Corral-Lage, Maguregui-Urionabarrenechea, and

Elechiguerra-Arrizabalaga 2019) and "social economy" (Chaves-Avila et al. 2016), which are also used by European Union institutions and in some European countries such as Portugal, Greece, Belgium and France (Monzón and Chaves 2012). This study focuses on Spain because it is more accessible to the authors than other countries but also due to the need for a better understanding of the third-sector reality in this country.

The third sector in Spain comprises 27.962 entities (Gómez Crespo and Cobo 2019), has 1.3 million volunteers and employs 644,979 persons (Ruiz *et al.*, 2015). The Spanish third sector is composed of a large variety of organizations that we can divide into the following 4 groups (Ruiz *et al.*, 2015):

- *First-level entities*: associations and foundations and base entities that do not group with others;
- *Second-level entities*: federations and entities that group with other entities (associations and foundations);
- *Third-level entities*: confederations and entities grouping together several federations; and
- *Singular entities*: entities at any level that have their own characteristics in terms of legal nature, degree of implementation, historical presence and recognition and social notoriety.

The Spanish third sector is formed mainly by entities within the first level (92%) such as Asociación Española Contra el Cáncer. Second- (e.g., Federación Española de Enfermedades Raras) and third-level (e.g., Plataforma del Voluntariado Español) organizations are a minority within the sector (7.7%) (Fundación Luis Vives 2012). Of all these organizations, three are considered "singular entities" (ONCE, Cruz Roja and Caritas) that represent the majority of the third sector volunteers and the employed paid staff (Price Waterhouse Coopers Foundation 2018; Ruiz Vilafranca et al. 2015). The singular organizations are, when examined at a great distance from the rest, the most senior ones (almost 100 years), but we cannot forget that these are entities with special characteristics that are far from the average of the third sector entities in Spain (Fundación Luis Vives, 2012).

Moreover, heterogeneity is a general feature of the Spanish third sector. The collaboration between Spanish third sector organizations is almost nonexistent, although they sometimes build alliances regarding lobbying activities or cooperate in specific areas (Chaves-Avila *et al.*, 2016).

Currently, the policy environment in Spain is highly decentralized and complex; public policies, funds and services come from national, regional and local governments (Sánchez-Hernández and Glückler 2019). Additionally, the third sector has difficulties with building long-term partnerships with these governments (Chaves-Avila *et al.*, 2016). The European guidelines and the lines of action and inclusion of society in the scientific process can easily reach large international CSOs, platforms or networks of organizations (Ahrweiler et al. 2019). However, most Spanish CSOs are small entities that belong to the first level (Fundación Luis Vives 2012). This implies that their level of action is local, that they have less staff and, generally, that they have scarce purchasing power (Corral-Lage, Maguregui-Urionabarrenechea, and Elechiguerra-Arrizabalaga 2019; Ruiz Vilafranca et al. 2015).

As we have seen, a central problem affecting the understanding of CSO participation in scientific research stems from lack of clarity regarding definitions and the nature of their participation (Ahrweiler et al. 2019; Rainey, Wakunuma, and Stahl 2017). Due to the potentially beneficial contribution that CSOs may have in the research and innovation processes, there is a need to understand their current participatory nature, limitations and expectations to propose effective engagement strategies.

This study therefore seeks to answer the following research questions:

> RQ 1. What is the current state of CSO participation throughout the R&D&I process?
>
> RQ 2. What are the barriers or limitations to enhancing such participation?
>
> RQ 3. What kind of relationship do CSOs wish to have with the science and technology system (if they want to have any)?

5. 2 Methodology

To answer these questions, we conducted 31 semi-structured interviews with CSO managers and delegated representatives based in Spain. The selection criteria were developed considering the different kinds of CSOs in Spain. We set up an advisory board specifically for this project, the specific details and degree of involvement with the study can be found in supplemental information.

5.2.1 Sampling

Intentional sampling was used to select the interviewees, and we selected a sample of strategic subjects based on their position (managers or delegated representatives with decision-making capacity) and the distribution of Spanish third sector entities (Fundación Luis Vives 2012), with the aim of including all the diverse social points of view as grouped by the following organizations: animalists, environmentalists, patients, parents, consumers, LGBTI+, etc. We wanted to include managers of the three singular entities that represent the majority of the third sector volunteers in Spain (Ruiz Vilafranca et al. 2015) in our sampling, but finally one of the three managers declined to be part of the study. All the organizations ultimately included in the study are non-profit.

Once the CSO representatives were identified, we sent them an e-mail describing the project and invited them to participate in an interview. Up to three follow-up emails and phone calls were made to solicit participation from those who did not respond. An additional effort was made to identify representatives working with traditionally underrepresented groups. Finally, 62 CSO representatives were contacted. Of these, 33 responded, two declined to be part of the study due to lack of time or interest, and interviews were completed with 31 people.

In Table 18, we summarize the final sample. More detailed information regarding the sample can be found in supplemental material.

Type of CSO	Number of entities
First-level entities	19
Second-level entities	7
Third-level entities	3
Singular entities	2
Total	31
Scope of action	**Number of entities**
Social	16
Environmentalist	7
Patients	8
Total	31

Table 18. Sampling description

The average age of the interviewed representatives was 49 years (SD=14), and there were more male (n=18) than female (n=13) CSO managers or representatives. Most interviewees had completed a higher education degree (n=26), and most of them had been linked to the CSO for more than 5 years (n=25). Before participating, all were informed of the nature of the study and the data processing policies, and they freely gave their consent. All of them were free to answer each one of the questions as well as to stop participating at any time.

5.2.2 Data collection and processing

The research team developed a semi-structured interview protocol following the guidelines of Silvia Rabionet (2011). The complete interview questions can be found on supplemental material. Two interviewers (the first author and a research team member) conducted face-to-face or Skype interviews according to interviewee preferences. The first interviewer conducted 22 interviews, and the second conducted 9 interviews. All the interviews were conducted between June and September 2017. The average interview took 54 minutes to complete, with the range spanning from 46 minutes to 78 minutes.

5.2.3 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 analyze the data and interpret its meaning with the support of the research software Atlas.ti (version 7.5). This research method represents the systematic and objective means of describing and quantifying phenomena (Schreier 2012). To do so, we reduced the data from interviews to codes or concepts that describe the research phenomena by creating categories, i.e., groups of content that share a commonality (Elo et al. 2014). The specific categories presented in the results section have been inductively determined from the interview data but, of course, our interpretation reflects previous categorizations such as the ones regarding different levels of public participation in science (Arnstein 1969; Bonney et al. 2009; Haklay 2013; Lewenstein 2004; Lidskog 2008; Rowe and Frewer 2004; Schrögel and Kolleck 2018).

Investigator triangulation and peer debriefing were the strategies used to ensure reliability. This strategy involved the use of more than one researcher during interview analysis to have a more detailed and balance picture of the situation. The two interviewers worked also as coders in coding the interview transcripts. They first coded a sample of interviews as means of calibration, then worked independently achieving a high degree of reliability. Discrepancies were discussed and resolved between coders and the other two authors.

Peer debriefing was used to ensure the collection of valid information. The first author did the first round of analysis of the code compilation, the second and third author reviewed the analysis and added their interpretations. The joint categorization resulting from this process was shared with the advisory board and presented in two internal seminars with the research team. Their inputs and feedback were also integrated in the final results analysis.

5.3 Results

In this section we present the results of the analysis of the interviews. In the following tables the main identified categories are described, we grouped interview references that fully coincide in their meaning with each category. If an interviewee makes more than one reference to the same concept throughout the interview, it is only quantified once. Frequencies has been used as a support resource for the results descriptions, since it is a qualitative research what is really valuable is the meaning that these concepts have which is detailed in each subsection.

5.3.1 Current participation in R&D&I

We grouped all interviewees mentions regarding different kinds of participation in science in categories that share a commonality. Table 19 summarizes the different categories, findings and frequencies of this dimension of study from all the interviews.

Category	Findings	Freq.
Unspecific collaboration s	Refers to different types of collaborations with universities, companies or other entities linked to R&D&I (agreements, internships, etc.).	17/31
To be subject of study	The representative, the members of the CSO or the CSO itself participate as subjects of research studies (interviews, clinical trials, etc.).	11/31
To collect data	The CSO or its members participate in the process of field work or data collection for an investigation carried out by an external institution.	9/31
To carry out research	Research carried out directly by the CSO.	9/31
To fund research	The CSO funds research related to its area of interest by seeking funds, awarding prizes or subcontracting other institutions to conduct research.	7/31
To advise	The representative, the CSO or some of its members have been consulted or are part of groups of people who advise in some way	7/31

	researchers or research projects that are related to the area of interest of the organization.	
To train	The representative, the CSO or its members participate in training activities at the university or in the research environment (conferences, master classes, mentoring, courses, etc.).	7/31
To not participate in research	The representative of the CSO considers that the organization does not participate in any way in the research system.	10/31

Table 19. Qualitative results of the "current participation in R&D&I" dimension of study, as analysed through a categorization system

a) Unspecific collaborations

On 13 occasions throughout the 31 interviews, we found references to some type of connection with universities, hospitals, research centres, companies or another entity linked in some way to research. However, these references were nonspecific. For example, there were references to "internships for scholars who work or develop research" at the CSO itself (e.g., Interview 19) or "students doing their PhD" (e.g., Interview 5). In this case, a formal link with the university or research centre would normally be required, but the interviewee has not given more information about it.

Other examples include mentions of being "in contact" (e.g., Interviews 23, 27, 29) with different entities or of "collaborating" (e.g., Interviews 6, 12, 21), "connecting" (e.g., Interviews 17, 29) or "participating" (e.g., Interview 5) with them. Some interviewees also mentioned some "agreements" with universities or other research entities (e.g., Interviews 8, 16, 25, 31), which also usually require a formal connection. However, in any of these mentions is the nature of the CSOs participation in research specified.

> "In fact, right now, at this moment, we are collaborating with the University and the Ministry of Health and Social Services in research; that is, in the preparation of the next state volunteering strategy." (Interview 21)

> "We are in contact with a research centre, we are in contact with the Ministry of Economy and Competitiveness, we are in contact with the Ministry of

> Agriculture, in its different lines, and also, well, we are in contact with universities. Well, I insist that our approach is to avoid the suffering of these animals as far as possible, where possible, and taking into account who is doing it, this forces us to be in contact with researchers." (Interview 27)

During the interviews, 4 CSO representatives made some reference to the usefulness of the research or innovation in their organization. These references may have been general about research and science (e.g., Interview 7) or about research in the specific field of action of the organization they represent (e.g., Interviews 13,14).

> "From our point of view, science can do much to improve the death of human beings by applying all kinds of technology, care and comfort at the end of life at a chemical level, not only at the orthopedic level..." (Interview 13)

In an organization of patients closely linked to the research, the manager made specific reference to the inclusion of the research in the action plan or strategic plan of the CSO.

> "Yes, it is included in our strategic plan; therefore, the research is in all the documents: in our annual operative plan, in the web page, in the memories, in the dossiers... It is a key aspect of our association." (Interview 15)

b) To be subject of study

The reference of participation in the science and technology system as a subject of study, for both the CSO itself and the associates or volunteers, was quite common. This is especially true regarding patient associations (e.g., Interviews 7, 12, 15), some of which even reported specific knowledge of the technical terminology, as we can see in the following quotes:

> "We have also collaborated on European projects at the research level by volunteering ourselves for post-clinical trials." (Interview 15)

> “If you need celiac people, we participate in that way. We do not have a laboratory, but we can contribute with other resources that they do not have.” (Interview 7)

We found it interesting that one of the interviewed managers indicated that people from the CSO are used as *"tools"* during investigations (Interview 5). On the other hand, there were some managers who referred to their participation in the "testing" of certain products to know the effect that they have on a specific group of people.

> “All that is part of a macro project; it is a research project in which the part we collaborate with is the testing and searching for solutions; we manage the incorporation of users with different profiles and then the testing. We verify the effect that each product or technology development has on disabled people.” (Interview 2)

There were also several CSO managers who related their participation in the research process by “giving information about the institution” (e.g., Interviews 14, 18, 22) or being interviewed by researchers (e.g., Interviews 1, 10). One of the interviewees even commented about "allowing researchers to stay in the same place as the residents so they can know their needs, or another type of observational work." *(Interview 16)*

c) To collect data

All the interviewees who made some reference to their connection with science and technology by referring to field work spoke of “collecting data or information" (e.g., Interviews 1, 8, 18, 29), “recording interviews” (e.g., Interview 19), “passing information" (e.g., Interview 11, 22, 28) or "developing the project" (e.g., Interview 16). Many of these cases are from environmental organizations, but this type of reference also appeared in relation to other kinds of organizations that are always linked to more social investigations and in reference to questionnaires or interviews that the CSO itself makes for an external entity (generally a university) that demands this information and analyzes the results.

> “We have a type of collaboration in which we collect a lot of important data about partner organizations. Data of all kinds; financial, human resources, activities... and we make this information available to researchers of the

> university so that they can make their analyses, extract data...” (Interview 8)

d) To carry out research

From the interviews, different types of investigations carried out by CSOs were identified. However, we grouped them all in the same category because we believe that the common meaning shared by all is the direct involvement of these organizations in a complete investigation, i.e., from establishing the objectives of the analysis to the publication of results. Another interesting point that emerged from the data is the emphasis made by many of the interviewees that their research is "purely social" (e.g., interview 13), even those CSOs who later comment about solid collaboration with research structures such as universities, hospitals or research centers (e.g., interview 9, 15, 24).

The majority of directors of CSOs who referred to the research carried out by their own organization meant research within the scope of their organization or with the aim of actually determining the status of their associates within a particular aspect of their scope:

> “Right now, we are conducting a study among our associates that seeks to determine the real picture of people with rare diseases: access to diagnosis, access to treatment, knowledge, coordination formulas; that is, social research.” (Interview 15)

Other entities, eminently third-level entities, have performed their own research for a long period of time; some of them also referred to the fact that the results of this research have not yet been published. This indicates, in part, knowledge of how the research process works.

> “We have been collecting data for 10 years, and we have volunteers who are analyzing this information so that in the future, we can publish the results. But it is a purely social investigation.” (Interview 13)

On the other hand, there are also larger associations with a greater research trajectory, for example, research carried out by the CSO in association with other research entities such universities.

> “We have been doing research at the academic level here in Spain and at the European level with other entities; this

> first approach has allowed us to open a line of work that has been financed with public and private funds." (Interview 30)

e) To fund research

Throughout the interviews, we also saw the linkage of CSOs as "charities", i.e., organizations set up to provide help and to raise money for those in need. However, 7 respondents referred to specific research funding that generally implies either giving money to a research entity (e.g., Interviews 12, 15, 16), hiring qualified personnel to carry out their own investigation (e.g., Interviews 8, 17), and even in some cases, specific calls for awards or grants for researchers (e.g., Interviews 2, 7). We found that this type of link with the research is more widespread among patient associations than other kinds of CSOs.

> "At this foundation, what we do at the moment is look for funds to endow research projects with resources." (Interview 15)

> "No, the foundation does not give money to science; we hire or give some economic help to a person who has the talent to get into the project." (Interview 17)

> "We give some research awards to support them economically so that they can continue researching." (Interview 7)

f) To advise

During the interviews, CSO representatives made reference to either themselves, the CSO or some of its members who have been consulted or are part of groups of people who advise in some way researchers or research projects.

Many times, an advisory board was not specifically mentioned, but the interviewees referred to a "consortium of people" (e.g., Interview 2), to "giving their opinion or information" (e.g., Interview 12, 19, 22) or to "giving support" (e.g., Interview 7) to research projects or research teams. In some cases, there were references to a more formalized collaboration that involve the writing of or, at least, collaboration about the drafting of terms of reference by which future research will be governed (e.g., Interviews 8).

> “Different groups of research on celiac disease in Spain have asked us to support their projects. They give us the research proposal, and we give them an opinion. So, yes, we are hand in hand with the research projects that are being carried out.” (Interview 7)

References to this type of collaboration with research are very diverse. Even so, we have unified them in the same group because their global meaning lies in the fact that the views or perceptions of the CSOs are integrated or, at least, taken into account during the research process.

g) To train

In reference to the question "Do you participate in research?", seven of the 31 interviewees mentioned their participation in training. This suggests that, for them, training activities focused on researchers (whether in the university or in other entities such enterprises or research centres) are part of their relationship with the science and technology system.

As seen in the following quotes, we found references to formal relationships with universities in which the CSO itself designs a whole course within a degree (e.g., Interviews 9, 12, 13, 18) or teaches voluntary training (e.g., Interview 21); there were more nonspecific references to "masters classes" (Interview 15) or “conferences” (Interview 14).

> “We are doing training for volunteer trainers in competitions. But we are doing it with a university and with specialized volunteer centres in other countries.” (Interview 21)

> “Group 9 is an association of nine public universities of autonomous communities where there is only one university […] and they proposed for us to design an entire course for which these universities will offer optative and free-elective credits.” (Interview 9)

h) To not participate in research

When we asked specifically about the respondents’ collaboration with the research, 10 of the 31 managers of CSOs indicated that they did not participate in any way. However, after several more questions, some of them ended up mentioning or explaining some kind of collaboration or connection with research (e.g., Interviews 5, 6, 8), generally social research. Despite these differences, we found it interesting to group all the opinions in the same category because they all shared the feeling of not being involved at any time in the research process.

> "We, as an organization, are not involved in the research; It's too pretentious to call what we do "research". That is, we do policy analysis, budget analysis, but to call it research would be too pretentious, I think." (Interview 8)

> "No. We have collaborated with other associations to do some kind of project, but not research." (Interview 4)

5.3.2 Limitations to participating in R&D&I

From the analysis of the interviews, we identified three categories regarding the limitations of CSOs regarding participating in R&D&I. Table 20 summarizes the categories, findings and frequencies of this study dimension.

Category	Findings	Frequency
Lack of resources	Refers to the limited resources of the CSO (financial, personnel, time...) as a major constraint for not participating in R&D&I.	11/31
Lack of mutual knowledge	Refers to the ignorance about the activity of the CSO by the research entities or the lack of knowledge by the CSO about the possibility of participating in R&D&I issues and/or the lack of communication between the two actors.	10/31
Lack of capabilities	Refers to the lack of skills (of the representative or members of the CSO) needed to conduct research.	2/31

Table 20. Qualitative results of the "limitations to participating in R&D&I" dimension of study, analysed through categorization system

a) Lack of resources

The limited resources of the CSO, such as financial (e.g., Interviews 5, 8, 13, 20, 21), personnel (e.g., Interviews 11, 29) or lack of time (e.g., Interviews 2, 8. 10, 11, 18, 23), seemed to be a major constraint for not participating in research.

> "The problem is the limitation of resources, basically, of economic resources. All the economic resources are for human resources… availability of time… Well, the more resources, the more things we do." (Interview 20)

> "We are very few people! This limits us a lot." (Interview 11)

b) Lack of mutual knowledge

In this category, we have grouped all the interviewees' mentions of the following: the lack of communication between the CSOs and the research entities (e.g., Interview 1, 22, 27), the lack of knowledge of the mechanisms needed to be able to participate in research (Interviews 4, 6, 14, 28), ignorance about the investigations that are being carried out (e.g., Interview 27) or the lack of knowledge about the activity of CSOs by the research entities (e.g., Interviews 5, 13, 15). It was decided to add all these ideas in the same category because, despite their differences, they share a common meaning of ignorance that could be improved or reduced with better communication.

For example, some CSO managers claimed that they "are not able to transfer well the potential that CSOs have for research" (Interview 22) or that "research and NGOs are two worlds that live separately and speak different languages" (Interview 27). Other interviewees referred to their own ignorance of how to participate in science, or they admitted that they have not considered it until now.

> "It is due to ignorance, not knowing where to go or how to offer our participation." (Interview 4)

> "Our organization is more focused on activism and, perhaps, we have not thought about that possible collaboration with the world of research." (Interview 14)

This conception of two isolated worlds was also found when interviewees talked about the "lack of knowing or lack of interest of trained professionals to do research in this area" (Interview 13). One interviewee even said that they do not participate in research because the sector to which their association is dedicated is "unlikely to be interesting for an investigation" (Interview 5). It is also important to note that one CSO representative blamed the lack of research on the social reluctance associated with the scope of action of their organization (child sexual abuse):

> "We work under a taboo area […] This means that there are no investigations. The taboo is present even in those places [hospitals, universities] where they should investigate; this is curious, but real." (Interview 1)

c) Lack of capabilities

Only two of the interviewees mentioned the lack of knowledge or lack of specific abilities needed to carry out research as a limitation to participation. This can be seen in the following quotes:

> "The problem is who among all of us is prepared to participate. Because here, we're not researchers." (Interview 12)

> "I do not consider myself qualified for research, nor am I of the right age to start all this." (Interview 6)

The fact that only 2 of the 31 interviewees refers to the lack of skills of the CSO members to carry out an investigation may reflect an overestimation of the CSO's capabilities.

5.3.3 Ideal relationship between the CSO and the R&D&I system

From the interviews, we identified five categories that refer to the relationship that CSO managers would like to have with the science and technology system. Table 21 summarizes them.

Category	Findings	Frequency
To strengthen links	Refers to strengthening the links between CSOs and the R&D&I system by stronger communication, formalized relationships and/or aligned objectives.	11/31
To request more research	Refers to the need for more research carried out by agents external to the CSO either at a generic level or in the specific field in which their CSO works.	5/31
To be consulted	Refers to the need for CSOs to be consulted on research topics related to their area of interest, either by forming part of a formalized advisory committee or through more informal consultations.	4/31
To be involved in R&D&I	Refers to the willingness of the CSO to participate in the R&D&I process by getting involved in the research, whether by carrying out field work, collecting data or as a "guinea pig" or subject of study.	3/31
To develop their own research	Refers to the willingness to carry out research activity within the CSO itself, including becoming a research centre	1/31

Table 21. Qualitative results of the "ideal relationship between the CSO and the R&D&I system" dimension of study, analysed through categorization system

a) To strengthen links

Throughout the interviews, we identified different needs that should be solved to strengthen the links between CSOs and the R&D&I system. For example, the need to "improve communication" (e.g., Interviews 7, 9, 11, 23, 27), to have a "fluid relationship" (e.g., Interview 5), to "strengthen relationships" (e.g., Interview 25) or "a greater proximity" (e.g., Interview 9) between scientists and NGOs were mentioned.

> "I think there should be a more fluid relationship with these entities, either those that finance, or those that execute research, which would be more logical. If there are people specialized in research, let them do it, but with our demands. And there is no fluid communication right now." (Interview 5)

Some CSO managers mentioned the need to establish "formalized relationships" (e.g., Interviews 24, 28) and "synergies or institutional relations" (e.g., Interview 15) or even the need to "reduce or solve the difference of the objectives between CSOs and research entities" (Interview 20) or a "greater continuity of the research projects" (Interview 24). We have grouped all these needs in the same category because they share the will to improve these relationships.

b) To request more research

From the analysis of the interviews, we can say that there is a need for more research carried out by agents who are external to the CSO, such as researchers at universities, hospitals or other research structures. Some interviewees mentioned research as a generic need (e.g., Interview 12), but most of them requested more research in the specific field of the CSO (e.g., Interviews 1, 5, 13, 14).

> "There are practically no neuroscience or neuroimaging studies on what happens in a person's body when they are dying because it is only studied from the point of view of the absence of health and, therefore, it is a failure." (Interview 13)

c) To be consulted

Some interviewees mentioned their intention to be part of a "formalized advisory board" (e.g., Interview 15) or, at least, "to be consulted" (e.g., Interviews 1, 3, 12) on research topics related to their area of interest. Moreover, they considered that this could "make and effective change" (e.g., Interview 1) and that it is a "need for the future" (e.g., Interview 12).

> "We want to be part of an advisory committee at the research level that also allows us to start future concrete lines of work within the association to open research projects" (Interview 15)

> "I think that all the people who are fighting against that can also be an active part of these changes, of that investigation, so that these professional people have a whole series of ideas and proposals and so that we can make an effective change. It is very necessary." (Interview 1)

d) To be involved in R&D&I

Three of the interviewees mentioned being a "guinea pig" (e.g., Interviews 12), "being used" (e.g., Interview 26) or "contributing with concrete data" (e.g., Interview 14) as the relationship that they want to establish with research. All these mentions shared the idea of participating directly in the research by providing data as the subjects of study or through field work.

> "Can we participate in an active way, as a federation, in research? …. Other than as being guinea pigs… I do not see another possibility." (Interview 12)

> "I would love for companies to see us as an option, for example, for testing their R&D&I… that is, we represent many women who have many problems, from sclerosis to maternity… therefore, anyone who developed a product and wanted to use us as a guinea pig, it would be fantastic, and I think that should be the relationship we should have." (Interview 26).

e) To develop their own research

One of the managers interviewed talked about the willingness to carry out research activity within the CSO itself:

> "I would love to go one step further and become a technology center. Of course, we would continue to be a foundation with the same statutes and activity but take that step further as a technological center, with a stable team of professionals dedicated to the line of research that we would establish. Now, we are working with researchers, managers, coordinators at universities or companies. But they are the ones who develop it; we want to be owners of the research. (Interview 2)

It is important to bear in mind that this reflection was made by a representative of a large CSO, with many affiliates and volunteers and with great economic potential.

5.4 Discussion

As far as the authors know, it is the first time that an exploratory study on CSOs-science relations has been carried out in Spain. This is interesting on the one hand, to gain a better understanding of the reality of Spain, a country very active in scientific research and which is recently promoting the inclusion of society in the research process. And, on the other, to allow comparisons with investigations in countries with similar social realities (Italy, Portugal, Greece, etc.). However, we must bear in mind that this is a qualitative study with an exploratory intention, our findings cannot be considered as representative of all the CSOs in Spain.

5.4.1 Current participation in R&D&I

The CSO representatives' interview analysis suggests that CSOs are actually participating in science, mainly through unspecific collaborations such as agreements and internships, as the subject of study or in data collection. This participation also includes advising research or research projects, funding research, participating in training activities and even carrying out their own research activities. However, many of the nonspecific relationships (e.g., research stays or students doing their PhD) mentioned in the interviews require an agreement, or some kind of formal relationship between the CSO and the academy.

The connection of academia, productive sector and CSOs for scholar or professional training is a valuable collaboration for all sectors. Of course, more research is needed to fully understand CSOs participation in science and how this participation is distributed among their scope of action.

Ahrweiler *et al.* reported that CSOs mainly participate in European research projects "to provide expert knowledge" and that project coordinators seemed to assign to CSOs a more passive role than that of other partners (Ahrweiler et al. 2019). Much of information regarding the CSOs' participation in science that emerged from the interviews refers to a one-time participation. Therefore, it seems that CSOs participate only in a research moment (with funding, as a subject of study, data collection, etc.), but they are not involved throughout the process, and it seems that they are even less involved in defining objectives. Co-responsibility can only be reached with broader stakeholder engagement in technical and scientific projects (Mejlgaard *et al.* 2018). This implies a much closer relationship, i.e., being part of the research, which means being involved in the whole process. Thus, more efforts are needed to promote CSO inclusion in the entire research process to be aligned with effective collaborative strategies.

We consider it interesting to highlight that the CSOs' participation in training activities was focused on research personnel. The CSO representatives understand this kind of collaboration as a way of participating in research. The sectoral knowledge and oversight that CSOs can provide in research (Bernauer and Gampfer 2013) could be a key issue in these training sessions. Of course, more research is needed to determine their nature and content.

On the contrary, a large part of the interviewees considered that they are not participating in research in any way; this is true even for those who ended up mentioning or explaining some kind of collaboration with research. This last condition is more widespread among CSOs that collaborate with universities in social research (for example, gathering field data, answering questionnaires or being interviewed). It seems that many of the interviewed managers do not see the value of their knowledge and do not consider these collaborations to be important or as participating in research.

Perhaps closer relationships with researchers or agreements with research entities are needed. Therefore, it is crucial for CSOs to become aware of their own potential for research. Only if both parties are aware of the mutual benefits of working together can we align efforts to build a more socially responsible science through transdisciplinary research. This implies that some efforts have to be made to promote CSO knowledge on science-related processes as well as collaborative methodologies to participate in research (Värmland County Administrative Board 2018).

5.4.2 Limitations to participating in R&D&I

The need for funding and the lack of time, training, CSO purposes and communication have been identified as the barriers to participating in research among interviewees. These issues should be addressed if CSO participation in science and technology is to become an integral part of scientific practice, as co-responsibility movements currently conceive to be the case.

The majority of Spanish CSOs are small local entities that are understaffed and have low economic capacity (Ruiz Vilafranca et al. 2015). Thus, the lack of personal and economic resources are intrinsic limitations of the third sector in Spain. Moreover, attracting funding from big funding bodies (e.g., the European Commission) would often require adopting their policies, thereby limiting the freedom of CSOs to maneuver (Ahrweiler et al. 2019). It is difficult to think of a solution for reducing this barrier beyond promoting the benefits that a CSO can have when participating in research.

However, the lack of knowledge between the scientific community and CSOs reported in the interviews is a barrier that could more easily be reduced. Although communication, public engagement and collaborative strategies have a fundamental role in the professional life of scientists and significant social implications, most of the universities in Spain do not include 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 that more align with co-responsibility objectives are needed.

Another possible solution could be to create formal communication channels so that CSOs know how they can participate in research, that such collaborations are wanted and, especially, that they are useful and beneficial for both parties. We believe that this type of effort should be encouraged from the government (local and national) and from the scientific institutions themselves (universities or research centres).

5.4.3 Ideal relationship with the R&D&I system

CSO representatives referred to formal associations with research entities through agreements to develop research work (undergraduate, masters or doctorate projects) or as part of advisory boards. However, different needs should be met to strengthen the links between CSOs and the science and technology system, including the lack of communication, the divergence of objectives, research timing and the lack of continuity.

The inclusion of CSO representatives as part of research advisory boards is closely related to the concepts of co-responsibility and the idea of democratization of science (Hockfield 2018). Furthermore, this fact merges the co-responsibility trend towards broader stakeholder engagement in technical and scientific projects with the willingness of CSO representatives to promote research within their scope of action.

Community-based research has increasingly been seen as having the potential to overcome some of the challenges of more standard research approaches, thereby strengthening the rigor and utility of science for community applicability (Lucero et al. 2018). We believe that a good way to try to strengthen the relations between the scientific community and CSOs is to promote this research approach. For example, universities can encourage it in final degree projects and masters' theses or even in doctoral programs. This kind of collaboration already exist in Spain, but could be foster and promoted among both science students and local CSOs.

5.5 Conclusions and future research

Due to the potentially beneficial contribution that CSOs may have in science and technology processes, there is a need to understand their current participatory nature, limitations and expectations to propose effective engagement strategies. In this article we have addressed the Spanish context by a qualitative approach with the aim to have an exploratory vision of the CSOs-science relationship. As such, our conclusions should not be over interpreted: further research is needed to fully understand Spanish CSOs 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.

Our findings suggest that the analyzed CSOs are mainly participating in science in a singular moment of the research. Thus, it seems that if public participation in science is going to be promoted, there could be beneficial to empower CSOs about the importance of their potential and sectoral knowledge. Moreover, all movements devoted to foster science-society relationships require including society from the beginning of the research process to build a more socially responsible science through transdisciplinary teams. To do so, we think that specific training programs regarding collaborative methodologies to accomplish such research approaches, both for CSO staff and researchers, can be beneficial.

The lack of funding, time, training, mutual knowledge and communication have been reported as the barriers for CSO participation in research. We consider that specific training for future scientists regarding communication skills, public engagement methodologies and how to establish collaborative relationships more aligned with co-responsibility can help to overcome some of these barriers. Additionally, we consider that it is important to establish formal channels for CSO inclusion in research. Also, promoting, among the CSOs, a better knowledge about the nature of science and research system could help to overcome these barriers.

Our findings suggest that the divergence of objectives and the lack of communication, research time and continuity should be solved to strengthen the links between CSOs and the science and technology system. We consider that, for example, community-based research approaches could be promoted through final degree projects, master theses or doctoral programs to foster CSOs-science relations.

5.6 Supplemental material

5.6.1 Advisory board description

An advisory formed by 10 members of 10 Spanish scientific culture units, which are structures formally recognized 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 reality within different parts of the country and especially due to their ability to identify potential CSOs for inclusion in the study.

Table 22 summarizes the institutions that formed part of this advisory board:

University or research centre	**City**	**Autonomous community**
University of Seville	Seville	Andalusia
University of Zaragoza	Zaragoza	Aragon
National Research Centre on Human Evolution (CENIEH)	Burgos	Castile and León
University Jaume I	Castellón	Community of Valencia
Polytechnic University of Madrid	Madrid	Madrid
University Carlos III	Madrid	Madrid
University of Cordoba	Córdoba	Andalusia
International University of La Rioja	Logroño	La Rioja
Seneca Foundation	Murcia	Murcia
AZTI-Tecnalia	Guipuzkoa	Basque Country

Table 22. Advisory board institutions

This advisory board collaborated with the research team throughout the study regarding several key points, namely, the definitions of the study dimensions, the revision of the scripts of the semi-structured interviews and the selection criteria of the candidates to be interviewed. We also relied on their experience during the discussion of the results and thus ensured the reliability of the interpretations. The units of scientific culture were selected by taking into account previous working connections and diversity of geographical distribution with the aim to have a broader view of other Spanish sectors.

5.6.2 Interview guidelines

INTERVIEWEED PROFILE

Name and surname: Level of studies: Age: Professional position: Time of labour linkage with the CSO:

CSO PROFILE

CSO name: CSO type: Location: Objective of the CSO: Number of affiliates:

RQ1 - Current state of CSO participation throughout the R&D&I process

- What is the purpose of your social organization / association?
- Does the entity you represent participate in research?
    - How has this participation been?
- When did the entity you represent participate in research? (ideas for research, definition of objectives, providing data, interpreting results, etc.)
    - Who conducted the research?
- Do you have any type of formal relationship established with entities that carry out research (universities, hospitals, research centres, etc.)?

RQ2 - Barriers or limitations to enhancing CSOs participation in research

- Has there been any reason that limited the entity's participation in research?
    - What reasons?
    - Can you give me an example?

RQ3 - Ideal relationship with R&D&I system

- How do you think your entity's participation in research could be enhanced?
- With what type of contributions do you think your entity can collaborate in research?

5.6.3 Sample description

Interview number	Gender	Type of CSO	Scope of action
1	Female	First level entity	Patients
2	Male	Singular entity	Patients
3	Male	First level entity	Patients
4	Male	First level entity	Environmentalist
5	Female	Second level entity	Social
6	Male	First level entity	Social
7	Male	Second level entity	Patients
8	Female	Second level entity	Social
9	Male	First level entity	Social
10	Male	Third level entity	Social
11	Female	First level entity	Social
12	Male	Second level entity	Social
13	Female	First level entity	Social
14	Female	First level entity	Social
15	Female	Second level entity	Patients
16	Male	Third level entity	Patients
17	Male	First level entity	Patients
18	Female	Second level entity	Social
19	Male	First level entity	Social
20	Male	First level entity	Social
21	Female	Third level entity	Social
22	Male	Singular entity	Social
23	Male	First level entity	Patients
24	Male	First level entity	Environmentalist
25	Female	Second level entity	Social
26	Female	First level entity	Social
27	Male	First level entity	Environmentalist
28	Female	First level entity	Environmentalist
29	Male	First level entity	Environmentalist
30	Male	First level entity	Environmentalist
31	Female	First level entity	Environmentalist

Table 23. Sample description

CHAPTER 6. GENERAL DISCUSSION

"L'art c'est moi, la Science c'est nous"
"Art is I; Science is we"

Claude Bernard
Physician

The three studies that made up this thesis have contributed to better understand the current situation of Spanish citizen participation in science. Concretely, our findings provide an exploratory view of current citizen participation practices in science. As far as the author knows, is the first time that scientists' perceptions of public has been studied in Spain and the same goes for the analysis on CSOs' participation in science. Therefore, the new knowledge generated with this thesis can be taken into account to propose strategies to foster citizen participation in science.

In Chapters 3 to 5 a detailed discussion for each study is included. This section therefore presents a summary of the general discussion and a relation of the reported results with the starting hypotheses.

6.1 Characteristics of Spanish citizen participation in science activities

As it is described in Chapter 3, the nature of the current Spanish participatory practices in science has been analysed through 16 semi-structured interviews to coordinators of such activities. This qualitative approach was aimed to have an exploratory vision of the stakeholders involved, the communication role in such practices and the degree of integration of the key requirements to develop a citizen participation in science practice.

6.1.1 Degree of integration of the key requirements

We have analysed the degree of integration of four key requirements: derived outputs, levels of participant's contributions, participation assessment and practice replicability. Besides, after the interviews' analysis a fifth requirement has been included: participants' and facilitators' training. Such five requirements must be taken into account in the project conceptualization phase, in order to allocate human and economic resources to those tasks not included in researchers' routine.

As we have seen in Chapter 3, participatory processes in science may require a training phase. Depending on the degree of participants' involvement it will be necessary to train them in specific skills (e.g., to data collection, analysis or interpretation). But also is important to anticipate the training needs of the research team in collaborative methodologies. Moreover, our results show that there is a huge confusion between participation assessment, data validation and assess satisfaction. Therefore, facilitators of such practices should be trained on methods to assess participation.

To carry out successful participatory practices is necessary to invest extra efforts in tasks that may exceed the competences of the research staff (e.g., identification of the potential stakeholders, engage participants, evaluation of the participation etc.). Of course, this may require a better training in such skills. But another approach, could be the creation of multidisciplinary teams to guarantee that there are people with the scientific-technical knowledge necessary to carry out the project and experts in communication, public engagement, co-production and deliberation strategies working in the same participatory project.

As reported in Chapter 4, Spanish scientists consider public engagement activities as a shared responsibility among institutional communication departments, journalists and researchers. This view of public engagement as a multidisciplinary activity that involves collaboration with diverse actors is consistent with the participatory approaches of science production. However, current literature describes that a large part of the scientific community continues to consider that the best way to approach the public is through the deficit model: one-way communication activities designed to educate the public and defend science from misinformation (Jensen and Holliman 2016; Metcalfe 2019; Seethaler et al. 2019; Simis et al. 2016).

This last understanding implies a passive audience and a bad perception of public's capacities that don't match with a participatory approach. Because participatory science must have an active citizen involvement that ends up with a contribution to the science and technology system either to respond to a specific research objective or to co-produce an output (e.g., legislation, decision-making etc.).

6.1.2 Public involved

This study has shown that although most of the coordinators of participatory practices in science mentioned the selection of strategic publics, some interviewees still consider the public involved in their projects as a single entity. However, in most cases the strategic public was students or the educational community which can be considered as a "captive public" (Fayard 1987) because the decision of participating was made by their teachers or schools.

As the inclusion of multiple publics in participatory science is necessary (Bernauer and Gampfer 2013; Frickel et al. 2010; Jacobi et al. 2017; Malyska, Bolla, and Twardowski 2016; Welp et al. 2006), is important that coordinators of such practices are able to identify the different publics that better fit with their project objectives. As Besley and Nisbet (2013) reported, researchers that have more experience in public engagement activities tend to also have a better understanding of multiple publics. We consider that including training in public engagement in scientists' career could help to have a more realistic view of publics.

6.1.3 Communication role

According to our results (see Chapter 3), communication plays an essential role for the citizen participation practices in science development, both for dissemination and for strengthen relationships with stakeholders. Despite that communication, public engagement and collaborative strategies have a fundamental role in the professional life of scientists, most of the universities in Spain do not include such training in science degrees (Revuelta 2018).

Similar results have been reported in Chapter 5 regarding the lack of communication between CSOs and academia. For citizen participation in science become real there is a need to promote the skills and value of science communication among researchers. However, as we have seen in Chapter 4, Spanish younger scientists tend to receive more specialized training in science communication and public engagement activities.

6.2 Scientists' perceptions on citizens and their role in public engagement

Until now, very little was known about Spanish scientists' perception of their public. The study reported in Chapter 4 analyses 1022 answers to an online survey and provides an overview of Spanish scientists' opinions and attitudes towards citizens' understanding of science and on researchers' role in public engagement activities. Such findings enabled us to identify the differences between scientists' perceptions of public and citizens' perceptions of science in order to propose some strategies to improve citizen participation in the research process.

6.2.1 Differences between Spanish scientists' views and public understanding of science

Most of the Spanish scientists still believe that the main barrier to society being involved in citizen participatory projects is the lack of knowledge and understanding of scientific reasoning. This perception is aligned with the above-mentioned deficit model (Seethaler et al. 2019). However, the participatory approaches of science production that are promoted worldwide are the ones focused on mutual learning and processes of co-creation of science (such the ones analysed in Chapter 3). Therefore, to citizen participation in science become real we need to improve both the citizen understanding of science but also the researchers' perception of publics capacity and understanding.

We have identified differences between researchers' perceptions and attitudes of the public and how the public responds in the FECYT surveys (2017). Mainly, these differences relate to the information sources used by the public, the level of researchers' recognition and the actual level of science education and interest in science and technology.

Scientists' views regarding science and researchers' recognition as well as public's level of science education are more negatives than the Spanish citizens' views reported in FECYT surveys. On the other hand, Spanish researchers consider that public is more interested in science and technology than what is reported in public perception of science studies. Being aware of such differences is useful to propose strategies to improve science-society relationships.

6.2.2 Spanish scientists and public engagement in science

Spanish scientists consider that science communication and public engagement activities are a shared responsibility among them, institutional communication offices and scientific journalists. This implies that there is a broad potential to strengthen collaborations among researchers and communication specialists to integrate multidisciplinary teams to carry out citizen participation projects as we suggested before.

Moreover, we have observed an increase in science communication formal training among younger generations. And also, that scientists' confidence in public capacities decreased with increasing age, this view again is more aligned with a deficit model approach. Torres-Albero et al. (2011) described the average profile of Spanish scientists involved in science communication: middle-aged men working in higher professional category. Thus, our findings may be explained by a relative lack of experience in such activities among the oldest cohorts (over 55 years) of scientists, this also seems likely in other countries (Besley and Nisbet 2013). Our hypothesis then, is that including formal training in public understanding of science, public engagement and science communication in research careers could help to improve this situation. Of course, more research must be carried out to better assess this issue.

6.3 Civil Society Organizations' perceptions on their role in the Spanish research process

As described in Chapter 5, this is the first time that an exploratory study on CSOs-science relations has been carried out in Spain. This qualitative study has been done through 31 semi-structured interviews to managers or delegated representatives of CSOs organizations based in Spain. However, we must bear in mind that this is a qualitative study with an exploratory intention, our findings cannot be considered as representative of all the CSOs in Spain.

6.3.1 Current participation in R&D&I

Most of the analysed CSOs are actually participating in science in a single research moment (with funding, as a subject of study, data collection, etc.), but they are not involved through the process, and even less in defining objectives. Moreover, many of the interviewed managers are not aware of their knowledge and do not consider their collaborations with academia to be important or as "participating in research". This last perception was more widespread among CSOs participating in social research (e.g., gathering field data, answering questionnaires or being interviewed).

However, effective citizen participation in science can only be reached with broader stakeholder engagement in the whole process (Mejlgaard et al. 2018). Thus, it is necessary for CSOs to become aware of their own potential to build a more socially responsible science. To be able to it, more efforts are needed to promote CSOs knowledge on science-related processes, to build a closer relationship with academia as well as establish collaborative methodologies for other stakeholders to participate in research.

6.3.2 Limitations to participating in R&D&I

CSO main action, lack of funding, time, training and knowledge (between scientific community and CSOs) are the identified main barriers to participating in research among interviewees. Lack of personnel and economic resources are intrinsic of Spanish CSOs; small local entities, understaffed and with low economic capacity (Ruiz Vilafranca et al. 2015). Thus, the only think that can be done to overcome this barrier is to promote the potential benefits of CSOs participation in research.

On the other hand, the lack of mutual knowledge between scientific community and CSOs (both reported in Chapter 4 and 5) could be reduced by improving communication. This can be done at an institutional level (e.g., creating formal communication channels) or by improving training on communication and collaborative skills among future scientists. Of course, both approaches need governmental support (local and national) but also a strong institutional commitment from universities and research centres.

6.3.3 Ideal relationship with the R&D&I system

As reported in Chapter 5, different needs should be met to strengthen the links between science and CSOs (e.g., lack of communication, divergence of objectives, research timing and lack of continuity). Most CSO representatives mentioned formal associations with academia to develop research work or being part of advisory boards as the main way to contribute in research.

Such inclusion is closely related to the co-responsibility concept and the idea of democratization of science (Hockfield 2018) but also is aligned with the CSO's willingness of promoting research within their scope. We consider that the "community-based research" approach can have the potential to overcome some of these challenges such divergence of objectives and lack of continuity. According to Lucero et al. (2018), this research approach can strengthen the rigour and utility of science for community applicability. Thus, a possible approach to foster CSOs-research institutions' relationship could be to promote this kind of research among young scientists (e.g., masters' theses or doctoral programs).

6.4 Relation with the starting hypotheses

The study reported in Chapter 3 and discussed in this section allows us to better understand the current citizen participation practices that are being carried out in Spain. As we have seen in Chapter 4 and also discussed in this Chapter, there are discrepancies between what Spanish scientists think the public perceives and what are actually Spanish society's perceptions of science. Hence, most researchers do not completely know their public, their capacities or the utility of involving civil society in science production.

On the other hand, as reported in Chapter 5 and discussed here, most of the CSOs managers or representatives are not aware of their own knowledge and the potential that they and their organizations have to foster a more socially relevant science. Moreover, we have identified a series of limitations that needs to be overcome to promote CSOs inclusion in research. Perhaps one of the most important, is the need for better communication to let CSOs know how they can intervene in science production.

With all this we can consider that the starting hypotheses of this thesis have been confirmed. In addition, the studies that constitute this thesis, despite its limitations, provide new results to date and, therefore, greater knowledge and understanding about citizen participation in science in Spain, as well as about the perceptions of two of the main actors involved (researchers and civil society). However, further research is needed to fully understand it. Thus, our findings should not be taken as definitive, but rather as the focus for potential strategies to foster science-society relationships.

CHAPTER 7. CONCLUSIONS

"Discourse and critical thinking are essential tools when it comes to securing progress in a democratic society. But in the end, unity and engaged participation are what make it happen."

Aberjhani
Historian and poet

Our research has allowed us to better understand the state of citizen participation in science and the perceptions of researchers and managers of civil society organizations (CSOs) in the Spanish context. This section outlines the main conclusions of the three studies that made up this thesis.

Regarding Spanish citizen participation practices:

- Five key requirements to develop a practice of citizen participation in science requirements need to be addressed before starting the participatory process in order to allocate necessary resources (both human and economic) to the out of the researchers' routine tasks: Derived outputs, levels of participant's contributions, participation assessment, practice replicability and participants' and facilitators' training.

- Participatory processes should take into account specific training needs:

    - for participants, depending on the degree and type of involvement, on specific scientific concepts or research skills.

    - for the research team, depending on the experience and/or background, on collaborative methodologies.

    - for facilitators on methodologies to assess the participatory process itself.

- 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).

- In participatory practices it is necessary to invest an extra effort during the conceptualization phase to identify the strategic stakeholders, the most appropriate strategies to recruit or engage participants and the expected level of commitment to the project.

Regarding scientists' perceptions of the public and their role in public engagement activities:

- Many scientists in Spain still believe that the lack of public scientific knowledge is the key hindrance to society being involved in public engagement activities.

- Confidence in the public capacities is lower among the most senior cohorts of researchers.

- There are some differences between the perceptions of scientists analysed and the perceptions of the public collected in the biannual reports of the FECYT. Specifically, these differences relate to the sources of information used by the public, the level of public recognition that science and researchers receive, the level of scientific education and the level of interest in science and technology.

- Scientists consider public engagement activities to be a shared responsibility among institutional communication departments, journalists and researchers.

- Younger generations of scientists tend to receive more specialized training in science communication.

Regarding CSOs managers' perceptions of participating in research:

- CSOs are mainly participating in science in a singular moment of the research and not during the entire process.

- CSOs managers are unaware of their own knowledge and potential in producing more socially relevant research.

- The lack of funding, time, training, mutual knowledge and communication are the main barriers to CSO participation in research.

- There is a need to solve the divergence of objectives, research continuity and lack of communication between CSOs and the academia to foster citizen participation in the science and technology system.

CHAPTER 8. CONTRIBUTIONS AND FUTURE IMPACTS

"Every kid starts out as a natural-born scientist, and then we beat it out of them. A few trickle through the system with their wonder and enthusiasm for science intact."

Carl Sagan
Astronomer and science communicator

Although citizen participation in science has been always a complex issue to treat, this thesis gives some evidences and reflections in the Spanish context. The main contribution of this work are the suggestions of potential strategies to overcome the identified barriers and challenges to foster participatory science.

Therefore, in this section such recommendations are summarized as well as the future research lines and thesis contributions to the sustainable development goals.

8.1 Recommendations to foster citizen participation in science

The findings of this thesis open the door to consider some strategies to foster citizen participation in science. First of all, the particularities and the multidisciplinary knowledge necessary to carry out participatory projects in science require an institutional commitment and even a governmental one. Such processes demand extra efforts for coordinators often out of the researchers' routine tasks. This implies that official recognition (e.g., to include specific items as evaluation criteria for hiring staff, career promotion or in funding calls, etc.) is needed in order to foster this research approach.

The role that communication plays in science-society relationships has been revealed as crucial for effective citizen participation projects. In this regard, promote training in communication skills among researchers could be a good approach to prepare future generations to carry out participatory processes. Such training could also prepare scientists to better understand publics and the potential benefits of citizen integration in science production.

There also has been highlighted other training needs such collaborative methodologies or methods for participation assessment that also could be integrated in research careers or, at least, offered to those researchers interested. Institutional actions promoting multidisciplinary collaboration between communication, outreach or public engagement departments and research groups could also enhance the effectiveness of this kind of research.

The results of this study suggest that CSOs are currently participating in science in a very limited way. It is important that scientific institutions take communication actions specifically aimed at CSOs to make them aware of the potential they have to produce a more socially relevant science. Moreover, institutional channels to foster CSOs inclusion in research (e.g., community based research approach) should be promoted both among researchers and CSOs.

8.3 Future research lines

After completing this research, various future research lines have been identified in which the author of this thesis is committed to moving forward. Thus, the proposed future is:

- To continue with the analysis of citizen participation projects in Spain to detect changes, progress and improvements in its implementation.
- To study the motivations, incentives, barriers and challenges that Spanish researchers have to engage in participatory scientific processes to be able to propose effective actions to enhance citizen participation in science.
- To continue studying the relationships of CSOs with the Spanish science and technology system, both of their managers and of partners and volunteers.
- To conduct an exploratory analysis of the relationship of the other main stakeholders (business sector and policy makers) with science and technology to better understand the Spanish situation.
- To analyse different approaches to teaching science communication, public engagement and collaborative strategies to identify and promote the most effective way to train researchers to conduct participatory science.

All the aforementioned lines of research need to be integrated into future studies to fully understand the science-society relations in Spain.

8.2 Sustainable development goals' contributions

It is desirable that all research contribute to some extent to one or more of the Sustainable Development Goals (SDGs). A previous reflection of how the work carried out in scientific or social research can influence society, allows align the research outputs with the SDGs. Therefore, this thesis cannot remain indifferent to these objectives.

The 17 SDGs are the heart of the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015. This agenda is an urgent call for action by all countries in a global partnership towards sustainability. And the SDGs are all global challenges facing humanity to achieve sustainability by 2030 (see Figure 15).

Figure 15. Sustainable Development Goals, United Nations infographic

The 17th goal "partnership for the goals", clearly identifies all levels of organization of society as key actors in the social transformation involving the adoption of the SDGs. This goal also calls for collaboration as the only way to move towards sustainability. Of course, all entities devoted to research are called to action through the incorporation of the SDGs into its missions but even more in this specific target. This is especially clear when it comes to academia and the three core missions of the university:

- Teaching for the transmission of knowledge, values and skills,
- Research and innovation to generate new knowledge and new solutions to the problems posed by society,

- Social responsibility, which includes the return to the knowledge society and the answers to the problems it raises.

As we have seen in previous sections, all this thesis seeks to gather better knowledge of science-society relationships to foster citizen participation in science. This new scenario of science production through citizen participation needs communication and co-creation skills to produce a more socially relevant science. Such kind of science, therefore, requires alliances and partnerships between different stakeholders (both locally and globally).

Even though there is no specific target included in this 17th SDG that perfectly fits with participatory science production, such approaches can foster a more socially relevant science, innovation and governance. This is completely aligned with the main SDGs objective, to collaboratively construct a better future. The citizen participation approaches analysed in this thesis are closely related to the five key competencies described by the United Nations to achieve sustainability (United Nations 2012). Specifically, with the following ones:

- **Systemic thinking competency**: The ability to recognize and understand relationships, analyse complex systems, think about how systems are integrated into different domains and scales, and deal with uncertainty.
- **Strategic competency**: The ability to collectively create and implement innovative actions that promote sustainability at the local level and beyond.
- **Collaboration competency**: The ability to learn from others, to understand and respect the needs, perspectives and actions of others (empathy), to understand others, to identify and be sensitive to them (empathic leadership), to address conflicts in groups and facilitate collaboration and participation in conflict resolution.
- **Integrated problem solving competency**: The global capacity to apply different conflict resolution frameworks to complex sustainability problems and to generate possible viable, inclusive and equitable solutions that promote sustainable development.

Therefore, the main contribution of this thesis in this regard is the analysis and proposals of strategies for the implementation of a co-creative model of science production and governance.

BIBLIOGRAPHY

Acevedo Díaz, José Antonio, Antonio García-Carmona, and María Del Mar Aragón. 2016. "Un Caso de Historia de La Ciencia Para Aprender Naturaleza de La Ciencia: Semmelweis y La Fiebre Puerperal." *Revista Eureka* 13(2): 408–22.

Ahrweiler, Petra et al. 2019. "The Role of Civil Society Organisations in European Responsible Research and Innovation." *Journal of Responsible Innovation* 6(1): 25–49.

Alcíbar, Miguel. 2015. "Comunicación Pública de La Ciencia y La Tecnología: Una Aproximación Crítica a Su Historia Conceptual." *Arbor* 191(773): a242.

Anderson, Annick, Jasmine Benger, and Ken Getz. 2019. "Using Patient Advisory Boards to Solicit Input Into Clinical Trial Design and Execution." *Clinical Therapeutics* 41(8): 1408–13.

Árnason, Vilhjálmur. 2013. "Scientific Citizenship in a Democratic Society." *Public Understanding of Science* 22(8): 927–40.

Arnstein, Sherry R. 1969. "A Ladder Of Citizen Participation." *Journal of the American Institute of Planners* 35(4): 216–24.

Bächtiger, André, John S. Dryzek, Jane J. Mansbridge, and Mark E. Warren. 2018. The Oxford Handbook of Deliberative Democracy *The Oxford Handbook of Deliberative Democracy*.

Bauer, Martin W, and Pablo Jensen. 2011. "The Mobilization of Scientists for Public Engagement." *Public Understanding of Science* 20(1): 3–11.

Baum, Howell S. 2001. "Citizen Participation." In *International Encyclopedia of the Social & Behavioral Sciences*, Pergamon, 1840–46.

———. 2015. "Citizen Participation." In *International Encyclopedia of the Social & Behavioral Sciences: Second Edition*, Elsevier, 625–30.

Bentley, R. Alexander et al. 2012. "Word Diffusion and Climate Science" ed. Sune Lehmann. *PLoS ONE* 7(11): e47966.

Berg, Monika, and Rolf Lidskog. 2018. "Deliberative Democracy Meets Democratised Science: A Deliberative Systems Approach to Global Environmental Governance." *Environmental Politics* 27(1): 1–20.

Bernauer, Thomas, and Robert Gampfer. 2013. "Effects of Civil Society Involvement on Popular Legitimacy of Global Environmental Governance." *Global Environmental Change* 23(2): 439–49..

Besley, John C., Anthony Dudo, Shupei Yuan, and Frank Lawrence. 2018. "Understanding Scientists' Willingness to Engage." *Science Communication* 40(5): 559–90.

Besley, John C., Sang Hwa Oh, and Matthew Nisbet. 2013. "Predicting Scientists' Participation in Public Life." *Public Understanding of Science* 22(8): 971–87.

Besley, John C, and Matthew Nisbet. 2013. "How Scientists View the Public, the Media and the Political Process." *Public understanding of science (Bristol, England)* 22(6): 644–59.

Bessette, Joseph M. 1980. "The Mild Voice of Reason: Deliberative Democracy and American National Government." *Journal of the Early Republic* 15(3): 519.

Blok, Anders, Mette Jensen, and Pernille Kaltoft. 2008. "Social Identities and Risk: Expert and Lay Imaginations on Pesticide Use." *Public understanding of science (Bristol, England)* 17(2): 189–209.

De Boer, Martine et al. 2005. "Public Understanding of Food Risk Issues and Food Risk Messages on the Island of Ireland: The Views of Food Safety Experts." *Journal of Food Safety* 25(4): 241–65.

Bohman, James., and William. Rehg. 1997. *Deliberative Democracy : Essays on Reason and Politics*. MIT Press..

Bonney, Rick et al. 2009. "Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy." *BioScience* 59(11): 977–84.

Brossard, Dominique, and Bruce Lewenstein. 2010. "A Critical Appraisal of Models of Public Understanding of Science: Using Practice to Informe Theory." In *Communicating Science: New Agendas in Communication*, eds. L Kahlor and PA Stout. New York: Routledge, 12–39.

Brown, Phil. 1997. "Popular Epidemiology Revisited." *Current Sociology* 45(3): 137–56.

Brownell, Sara E, Jordan V Price, and Lawrence Steinman. 2013. "Science Communication to the General Public: Why We Need to Teach Undergraduate and Graduate Students This Skill as Part of Their Formal Scientific Training." *Journal of undergraduate neuroscience education : JUNE : a publication of FUN, Faculty for Undergraduate Neuroscience* 12(1): E6–10.

Brulle, Robert J., and David N. Pellow. 2006. "ENVIRONMENTAL JUSTICE: Human Health and Environmental Inequalities." *Annual Review of Public Health* 27(1): 103–24.

Buiatti, M, P Christou, and G Pastore. 2013. "The Application of GMOs in Agriculture and in Food Production for a Better Nutrition: Two Different Scientific Points of View." *Genes & nutrition* 8(3): 255–70.

Burningham, K. et al. 2007. “Industrial Constructions of Publics and Public Knowledge: A Qualitative Investigation of Practice in the UK Chemicals Industry.” *Public Understanding of Science* 16(1): 23–43.

Calder, Ian. 2002. “Forests and Hydrological Services: Reconciling Public and Science Perceptions.” *Land Use and Water Resources Research* 2(2): 1–12.

Capeáns, Rosa, César López, and Gonzalo Remiro. 2012. *Libro Blanco de Las Unidades de Cultura Científica y de La Innovacción UCC+i*. ed. Fundación Española para la Ciencia y la Tecnología. Madrid

Carayannis, Elias G., and David F.J. Campbell. 2009. “‘Mode 3’ and ‘Quadruple Helix’: Toward a 21st Century Fractal Innovation Ecosystem.” *International Journal of Technology Management* 46(3–4): 201–34.

Carver, Steve. 2001. “Participation and Geographical Information: A Position Paper.” In *ESF-NSF Workshop on Access to Geographic Information and Participatory Approaches Using Geographic Information*, ed. University of Leeds. Spoleto, 1–19.

Chakraborty, Ganwesha, and Rita Giuffredi. 2020. “Science and Technology for the People? On the Framing Ofinnovation in Policy Discourses in India and in EU.” *Journal of Science Communication* 2011(2865): 1–9.

Chaves-Avila, Rafael, Pilar Algucil-Mari, Isabel Gemma Fajardo-Garcia, and Teresa Savall-Morera. 2016. TSI National Report Series No. 8. Seventh Framework Programme (grant agreement 613034) *National Report on Third Sector Barriers in Spain*. Bruselas.

Chilvers, Jason. 2013. “Reflexive Engagement? Actors, Learning, and Reflexivity in Public Dialogue on Science and Technology.” *Science Communication* 35(3): 283–310.

Collins, Kimberley, David Shiffman, and Jenny Rock. 2016. “How Are Scientists Using Social Media in the Workplace?” ed. Stefano Goffredo. *PLOS ONE* 11(10): e0162680.

Cook, Guy, Elisa Pieri, and Peter T. Robbins. 2004. “‘The Scientists Think and the Public Feels’: Expert Perceptions of the Discourse of GM Food.” *Discourse & Society* 15(4): 433–49.

Cooper, C.B., and B.V. Lewenstein. 2016. “Two Meanings of Citizen Science.” In *The Rightful Place of Science: Citizen Science*, eds. D. Kennedy and E.B. Kennedy. , 51–62.

Cornell, Sarah et al. 2013. “Opening up Knowledge Systems for Better Responses to Global Environmental Change.” *Environmental Science and Policy* 28: 60–70.

Corral-Lage, Javier, Lorea Maguregui-Urionabarrenechea, and Crisanta Elechiguerra-Arrizabalaga. 2019. “Estudio Empírico Del Tercer Sector En España: Hacia

Una Re-Conceptualización Unificada." *Revista de Contabilidad* 22(2): 145–55.

Curtis, Vickie. 2014. "Online Citizen Science Projects: An Exploration of Motivation, Contribution and Participation." The Open University.

Dahl, Robert A. 2005. *Who Governs?: Democracy and Power in an American City*. Yale University Press.

Davies, Sarah et al. 2009. "Discussing Dialogue: Perspectives on the Value of Science Dialogue Events That Do Not Inform Policy." *Public Understanding of Science* 18(3): 338–53.

Davies, Sarah R. 2008. "Constructing Communication: Talking to Scientists About Talking to the Public." *Science Communication* 29(4): 413–34.

Davies, Sarah R., and Maja Horst. 2016. "Scientific Citizenship: The Role of Science Communication in Democracy." In *Science Communication*, Palgrave Macmillan UK, 187–211.

Davies, Sarah R., Cynthia Selin, Gretchen Gano, and Ângela Guimarães Pereira. 2012. "Citizen Engagement and Urban Change: Three Case Studies of Material Deliberation." *Cities* 29(6): 351–57.

Defourny, Jacques. 2013. "The Third Sector." In *Handbook on the Economics of Reciprocity and Social Enterprise*, eds. Luigino Bruni and Stefano Zamagni. Cheltenham, UK: Edwar Elgan Publisher, 400–410.

Dillman, Don A., Jolene D. Smyth, Leah Melani. Christian, and Don A. Dillman. 2009. *Internet, Mail, and Mixed-Mode Surveys : The Tailored Design Method.* Wiley & Sons.

Doh, Jonathan P., and Terrence R. Guay. 2006. "Corporate Social Responsibility, Public Policy, and NGO Activism in Europe and the United States: An Institutional-Stakeholder Perspective." *Journal of Management Studies* 43(1): 47–74.

Donkor, Felix Kwabena et al. 2019. "Climate Services and Communication for Development: The Role of Early Career Researchers in Advancing the Debate." *Environmental Communication* 13(5): 561–66.

Dudo, Anthony et al. 2016. "Scientists' Prioritization of Communication Objectives for Public Engagement." ed. Fulvio d'Acquisto. *PloS one* 11(2): e0148867.

Dunwoody, Sharon, Dominique Brossard, and Anthony Dudo. 2009. "Socialization or Rewards? Predicting U.S. Scientist-Media Interactions." *Journalism and Mass Communication Quarterly* 86(2): 299–314.

Duschl, Richard A., and Richard Grandy. 2013. "Two Views About Explicitly Teaching Nature of Science." *Science and Education* 22(9): 2109–39.

Ecklund, Elaine Howard, Sarah A. James, and Anne E. Lincoln. 2012. "How Academic Biologists and Physicists View Science Outreach" ed. Luís A. Nunes Amaral. *PLoS ONE* 7(5): e36240.

Eitzel, M V et al. 2017. "Citizen Science Terminology Matters: Exploring Key Terms." *Citizen Science: Theory and Practice* 2(1): 1–20.

Elo, Satu et al. 2014. "Qualitative Content Analysis." *SAGE Open* 4(1): 215824401452263.

Elzen, Boelie, Frank W. Geels, Cees Leeuwis, and Barbara Van Mierlo. 2011. "Normative Contestation in Transitions 'in the Making': Animal Welfare Concerns and System Innovation in Pig Husbandry." *Research Policy* 40(2): 263–75.

Epstein, Steven. 1995. "The Construction of Lay Expertise: AIDS Activism and the Forging of Credibility in the Reform of Clinical Trials." *Science, Technology, & Human Values* 20(4): 408–37.

European Commission. 2005. *Europeans, Science and Technology*. Brussels.

———. 2007. *Public Engagement in Science*. Brussels.

———. 2008. *Europeans' Attitudes towards Climate Change*. 145. Brussels.

———. 2010a. *Europeans and Biotechnology in 2010. Winds of Change?* Brussels.

———. 2010b. *Science and Technology Special Eurobarometer*. Brussels.

———. 2014. 92 *Responsible Research and Innovation: Europe's Ability to Respond to Societal Challenges*. Brussels.

———. 2014. *Horizon 2020 "Science with and for Society" Providing Advice on Potential Priorities for Research and Innovation in the Work Programme 2016–2017 Consultation Paper*. Brussels.

———. 2015. *Validation of the Results of the Public Consultation on Science 2.0: Science in Transition*. Brussels.

———. 2020. *Progress on Open Science: Towards a Shared Research Knowledge System*. Brussels.

European Science Foundation. 2013. *Science in Society: Caring for Our Futures in Turbulent Times (Science Policy Briefing No. 50)*.

Farrell, David M., Jane Suiter, and Clodagh Harris. 2019. "'Systematizing' Constitutional Deliberation: The 2016–18 Citizens' Assembly in Ireland." *Irish Political Studies* 34(1): 113–23.

Fayard, Pierre. 1987. "La Professionnalisation et l'émergence Médiatique de La Communication Scientifique à Destination Des Non-Spécialistes." Université Stendhal (Grenoble).

Fecher, Benedikt, and Sascha Friesike. 2014. "Open Science: One Term, Five Schools of Thought." In *Opening Science: The Evolving Guide on How the Internet Is Changing Research, Collaboration and Scholarly Publishing*, eds. Sönke Bartling and Sascha Friesike. London: Springer Open, 17–48.

Felt, Ulrike. 2007. European Comission *Taking European Knowledge Society Seriously*. Belgium.

Fernández Beltrán, Francisco José, and Vicente Domingo García Marzá. 2017. Ética y comunicación en la gestión de la Investigación e Innovación Responsable (RRI): el papel de las Unidades de Cultura Científica y de la Innovación (UCC+i). *Ética y Comunicación En La Gestión de La Investigación e Innovación Responsable (RRI): El Papel de Las Unidades de Cultura Científica y de La Innovación (UCC+i).*

Fisher, Dana R. 2019. "The Broader Importance of #FridaysForFuture." *Nature Climate Change* 9(6): 430–31. http://www.nature.com/articles/s41558-019-0484-y (December 28, 2019).

Frickel, Scott et al. 2010. "Undone Science: Charting Social Movement and Civil Society Challenges to Research Agenda Setting." *Science Technology and Human Values* 35(4): 444–73.

Fundación Española para la Ciencia y la Tecnología (FECYT). 2017. "Percepción Social de La Ciencia y La Tecnología 2016." : 380.

Fundación Luis Vives. 2012. Fundación Luis Vives, Madrid *Anuario Del Tercer Sector de Acción Social En España*. Madrid.

Funk, Cary, Lee Rainie, and Aaron Smith. 2015. "Public and Scientists' Views on Science and Society." *Pew Research Center* 1–93: 1–18.

Gallagher, Rachael et al. 2019. "The Open Traits Network: Using Open Science Principles to Accelerate Trait-Based Science across the Tree of Life." *EcoEvoRxiv* (April): 1–25.

García-Carmona, Antonio, José Antonio Acevedo-Díaz, and María del Mar Aragón. 2018. "Comprensión de Estudiantes de Secundaria Sobre La Dimensión Sociológica de La Naturaleza de La Ciencia a Partir de La Historia de La Ciencia." *Ápice. Revista de Educación Científica* 2(2): 43–54.

Gascoigne, Toss, and Jenni Metcalfe. 1997. "Incentives and Impediments to Scientists Communicating through the Media." *Science Communication* 18(3): 265–82.

Gibbons, Michael. 1999. "Science's New Social Contract with Society." *Nature*

402(6761 SUPPL. 1).

Godden, Naomi Joy. 2017. "The Participation Imperative in Co-Operative Inquiry: Personal Reflections of an Initiating Researcher." *Systemic Practice and Action Research* 30(1): 1–18.

Gómez Crespo, María, and Antonio Cobo. 2019. *Informe de Elaboración Del Directorio Del Tercer Sector de Acción Social.*

Gómez, Isabel, Rosa Sancho, María Bordons, and María Teresa Fetnández. 2006. "La I + D En España a Través de Publicaciones y Patentes." In *Radiografía de La Investigación Pública En España*, eds. Jesús Sebastián and Emilio Muñoz. Madrid: Biblioteca Nueva, 275–302.

Grand, Ann, Gareth Davies, Richard Holliman, and Anne Adams. 2015. "Mapping Public Engagement with Research in a UK University." *PLoS ONE* 10(4): 1–19.

Gregory, Jane, and Simon Jay Lock. 2008. "The Evolution of 'Public Understanding of Science': Public Engagement as a Tool of Science Policy in the UK." *Sociology Compass* 2(4): 1252–65.

Haenssgen, Marco J. 2019. "New Impulses from International Development for More Comprehensive and Balanced Public Engagement Evaluation." *Global Health Action* 12(sup1): 1680067.

Hagendijk, Rob, and Alan Irwin. 2006. "Public Deliberation and Governance: Engaging with Science and Technology in Contemporary Europe." *Minerva* 44(2): 167–84.

Haklay, Muki. 2013. "Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation." In *Crowdsourcing Geographic Knowledge*, eds. D. Sui, S Elwood, and M Goodchild. Dordrecht: Springer, 105–22.

———. 2018. "Participatory Citizen Science." In *Citizen Science: Innovation in Open Science, Society and Policy*, eds. Susanne Hecker et al. UCL Press, 52–62.

Halpin, Darren. 2012. "Contemporary Politics in Australia : Theories, Practices and Issues." In *Contemporary Politics in Australia : Theories, Practices and Issues*, , 177–87.

Hayward, Chris, Lyn Simpson, and Leanne Wood. 2004. "Still Left out in the Cold: Problematising Participatory Research and Development." *Sociologia Ruralis* 44(1): 95–108. http://doi.wiley.com/10.1111/j.1467-9523.2004.00264.x (May 15, 2020).

Hess, David J., and Jonathan S. Coley. 2012. "Wireless Smart Meters and Public Acceptance: The Environment, Limited Choices, and Precautionary Politics." *Public Understanding of Science* 23(6): 1–15.

Hilmer, Jeffrey D. 2010. "The State of Participatory Democratic Theory." *New Political Science* 32(1): 43–63.

Hockfield, Susan. 2018. "Our Science, Our Society." *Science* 359(6375): 499–499.

Hojnacki, Marie. 1999. "The Conspicuous Corporation: Business, Public Policy, and Representative Democracy . Neil J. Mitchell." *The Journal of Politics* 61(1): 269–71.

Horst, Maja. 2008. "In Search of Dialogue: Staging Science Communication in Consensus Conferences." In *Communicating Science in Social Contexts*, Dordrecht: Springer Netherlands, 259–74.

Horst, Maja, and Mike Michael. 2011. "On the Shoulders of Idiots: Re-Thinking Science Communication as 'Event.'" *Science as Culture* 20(3): 283–306.

Van der Hoven, Jeroen et al. 2013. *Options for Strengthening Responsible Research and Innovation*. Brussels.

Illingworth, Samuel M., and Heidi A. Roop. 2015. "Developing Key Skills as a Science Communicator: Case Studies of Two Scientist-Led Outreach Programmes." *Geosciences* 5(1): 2–14.

Instituto Nacional de Estadística. 2014. "Gastos Internos Totales y Personal En I+D Por Comunidades Autónomas y Tipo de Indicador." *Estadística de I+D 2014*.

Irwin, Alan. 1995. *Citizen Science : A Study of People, Expertise, and Sustainable Development*. Routledge.

———. 2001. "Constructing the Scientific Citizen: Science and Democracy in the Biosciences." *Public Understanding of Science* 10(1): 1–18.

Jacobi, Johanna et al. 2017. "Whose Knowledge, Whose Development? Use and Role of Local and External Knowledge in Agroforestry Projects in Bolivia." *Environmental Management* 59(3): 464–76.

Jenkins, Henry et al. 2009. *Confronting the Challenges of Participatory Culture*.

Jennett, Charlene et al. 2016. "Motivations, Learning and Creativity in Online Citizen Science." *Journal of Science Communication* 15(03): A05.

Jensen, Eric, and Richard Holliman. 2016. "Norms and Values in UK Science Engagement Practice." *International Journal of Science Education, Part B: Communication and Public Engagement* 6(1): 68–88.

Kapstein, Ethan B., and Joshua William Busby. 2016. "Social Movements and Market Transformations: Lessons From HIV/AIDS and Climate Change: Table 1." *International Studies Quarterly* 60(2): 317–29.

Kohler, Robert E. 2002. "Place and Practice in Field Biology." *History of science; an annual review of literature, research and teaching* 40(128 Pt 2): 189–210.

Krabbenborg, Lotte, and Henk A.J. Mulder. 2015. 37 Science Communication *Upstream Public Engagement in Nanotechnology: Constraints and Opportunities*.

Kullenberg, Christopher, and Dick Kasperowski. 2016. "What Is Citizen Science? – A Scientometric Meta-Analysis" ed. Pablo Dorta-González. *PLOS ONE* 11(1): e0147152.

Leshner, Alan I. 2007. "Outreach Training Needed." *Science (New York, N.Y.)* 315(5809): 161.

Leung, M. W, Irene H Yen, and Meredith Minkler. 2004. "Community Based Participatory Research: A Promising Approach for Increasing Epidemiology's Relevance in the 21st Century." *International Journal of Epidemiology* 33(3): 499–506.

Lewenstein, Bruce V. 2004. "What Does Citizen Science Accomplish?" In *Meeting on Citizen Science*, , 1–8.

Lidskog, Rolf. 2008. "Scientised Citizens and Democratised Science. Re-Assessing the Expert-Lay Divide." *Journal of Risk Research* 11(1): 69–86.

Lindberg, Malin, Monica Lindgren, and Johann Packendorff. 2014. "Quadruple Helix as a Way to Bridge the Gender Gap in Entrepreneurship: The Case of an Innovation System Project in the Baltic Sea Region." *Journal of the Knowledge Economy* 5(1): 94–113.

Liston, Mary. 2019. "Expanding the Parameters of Participatory Public Law: A Democratic Right to Public Participation and the State's Duty of Public Consultation." *McGill Law Journal* 63(2): 375–416.

Llorente, Carolina, Gema Revuelta, Mar Carrió, and Miquel Porta. 2019. "Scientists' Opinions and Attitudes towards Citizens' Understanding of Science and Their Role in Public Engagement Activities." *PLoS ONE* 14(11): 1–20.

Lopez, Lourdes, and María Dolores Olvera-Lobo. 2017. "Public Communication of Science in Spain: A History yet to Be Written." *Journal of Science Communication* 16(03): Y02.

Lucero, Julie et al. 2018. "Development of a Mixed Methods Investigation of Process and Outcomes of Community-Based Participatory Research." *Journal of Mixed Methods Research* 12(1): 55–74.

Macey, Gregg P et al. 2014. "Air Concentrations of Volatile Compounds near Oil and Gas Production: A Community-Based Exploratory Study." *Environmental Health* 13(1): 82.

Malyska, Aleksandra, Robert Bolla, and Tomasz Twardowski. 2016. "The Role of Public Opinion in Shaping Trajectories of Agricultural Biotechnology." *Trends in Biotechnology* 34(7): 530–34.

Manin, Bernard. 1987. "On Legitimacy and Political Deliberation." *Political Theory* 15(3): 338–68.

Mansbridge, Jane J. 1983. *Beyond Adversary Democracy*. University of Chicago Press.

Martin-Sempere, M. J., B. Garzon-Garcia, and J. Rey-Rocha. 2008. "Scientists' Motivation to Communicate Science and Technology to the Public: Surveying Participants at the Madrid Science Fair." *Public Understanding of Science* 17(3): 349–67.

Martín Izard, Juan Francisco. 2010. "Técnicas de Encuesta: Cuestionarios y Entrevista." In *Principios, Métodos y Técnicas Esenciales Para La Investigación Educativa*, ed. Santiago Nieto Martín. Madrid: DYKINSON, 145–68.

Mejlgaard, Niels et al. 2018. "Teaching Responsible Research and Innovation: A Phronetic Perspective." *Science and Engineering Ethics*: 1–19.

Mercer, Claire, and Maia Green. 2013. "Making Civil Society Work: Contracting, Cosmopolitanism and Community Development in Tanzania." *Geoforum* 45: 106–15.

Metcalfe, Jenni. 2019. "Comparing Science Communication Theory with Practice: An Assessment and Critique Using Australian Data." *Public Understanding of Science* 28(4): 382–400.

Miller, Jon D. 1998. "The Measurement of Civic Scientific Literacy." *Public Understanding of Science* 7(3): 203–23.

Monzón, José Luis, and Rafael Chaves. 2012. *The Social Economy in the European Union*.

MoRRI consortium. 2018. *The Evolution of Responsible Research and Innovation in Europe: The MoRRI Indicators Report (D4.3).* http://www.technopolis-group.com/wp-content/uploads/2018/02/D4.3_Revised_20022018_clean.pdf (July 24, 2019).

Moss, Stephen. 2005. *A Bird in the Bush : A Social History of Birdwatching.* Aurum Press.

Mulder, Henk A. J., Nancy Longnecker, and Lloyd S. Davis. 2008. "The State of Science Communication Programs at Universities Around the World." *Science Communication* 30(2): 277–87.

National Science Board. 2018. *Science and Engineering Indicators.*

Nielsen, Jakob. 2006. "Participation Inequality: The 90-9-1 Rule for Social Features." *Nielsen Norman group.*

Niessen, Christoph, and Min Reuchamps. 2019. *Designing a Permanent Deliberative Citizens Assembly: The Ostbelgien Modell in Belgium.*

Nugroho, Yanuar. 2011. "Opening the Black Box: The Adoption of Innovations in the Voluntary Sector—The Case of Indonesian Civil Society Organisations." *Research Policy* 40(5): 761–77.

OECD. 2016. OECD Publishing *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy,*. OECD.

Ott, Mary A., and Amelia S. Knopf. 2019. "Avoiding a Tyranny of the Majority: Public Deliberation as Citizen Science, Sensitive Issues, and Vulnerable Populations." *American Journal of Bioethics* 19(8): 28–31.

Ottinger, Gwen. 2010. "Buckets of Resistance: Standards and the Effectiveness of Citizen Science." *Science, Technology, & Human Values* 35(2): 244–70.

Pain, Elisabeth. 2013. "Spain's Research Council Approaches Bankruptcy." *Science* 341(6143): 225.

Palmer, Sarah E., and Renato A. Schibeci. 2014. "What Conceptions of Science Communication Are Espoused by Science Research Funding Bodies?" *Public Understanding of Science* 23(5): 511–27.

Pateman, Carole. 1970. *Participation and Democratic Theory.*

Perrault, Sarah. 2015. 24 Technical Communication Quarterly *Communicating Popular Science: From Deficit to Democracy.*

Porlezza, Colin. 2019. "From Participatory Culture to Participatory Fatigue: The Problem With the Public." *Social Media + Society* 5(3): 205630511985668.

Powell, M. C., Maria Colin, and Mathilde Powel. 2009. "Participatory Paradoxes: Facilitating Citizen Engagement in Science and Technology From the Top-Down?" *Bulletin of Science Technology Society* 29(4): 325–42.

Price Waterhouse Coopers Foundation. 2018. *Radiografía Del Tercer Sector Social En España: Retos y Oportunidades En Un Entorno Cambiante.* Madrid.

Rabionet, Silvia E. 2011. "How I Learned to Design and Conduct Semi-Structured Interviews: An Ongoing and Continuous Journey." *The Qualitative Report* 16(2): 563–66.

Raddick, M. Jordan et al. 2010. "Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers." *Astronomy Education Review* 9(1).

Rainey, Stephen, Kutoma Wakunuma, and Bernd Stahl. 2017. "Civil Society Organisations in Research: A Literature-Based Typology." *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations* 28(5): 1988–2010.

Rasheed, A. Rifaee, and Ameer Abdulla. 2020. "Evaluating Stakeholder Participatory Processes in Policy Development for Marine Protected Areas." *Marine Policy* 112: 103737.

RecerCaixa. 2016. *Impacte de La Introducció de La Ciència Ciutadana a Les Escoles*. Barcelona.

Reed, Jason, M. Jordan Raddick, Andrea Lardner, and Karen Carney. 2013. "An Exploratory Factor Analysis of Motivations for Participating in Zooniverse, a Collection of Virtual Citizen Science Projects." In *2013 46th Hawaii International Conference on System Sciences*, IEEE, 610–19.

Regalado, Antonio. 2010. "Spain Turns to Science for Stimulus." *Science*.

Rensberger, Boyce. 2009. "Science Journalism: Too Close for Comfort." *Nature* 459: 1055–56.

Revuelta, Gema. 2014. "Impacts of Science Communication on Publics, Cities and Actors." *Journal of Science Communication* 13(1): 1824–2049.

———. 2018. "Formación En Comunicación En Los Estudios de Grado Análisis En Las Áreas de Ciencias de La Salud y La Vida, Ciencias Ambientales y Ciencias Naturales." *InMediaciones de la Comunicación* 13(2): 159–82.

Roberts, Nancy. 2004. "Public Deliberation in an Age of Direct Citizen Participation." *The American Review of Public Administration* 34(4): 315–53.

Rogers, Kevin H. 2006. "The Real River Management Challenge: Integrating Scientists, Stakeholders and Service Agencies." *River Research and Applications* 22(2): 269–80.

Rowe, Gene, and Lynn J. Frewer. 2004. "Evaluating Public-Participation Exercises: A Research Agenda." *Science, Technology, & Human Values* 29(4): 512–56.

Ruiz Vilafranca, R. et al. 2015. *El Tercer Sector de Acción Social En 2015: Impacto de La Crisis*. Madrid.

de Saille, Stevienna. 2015. "Innovating Innovation Policy: The Emergence of 'Responsible Research and Innovation.'" *Journal of Responsible Innovation* 2(2): 152–68.

Sánchez-Hernández, José Luis, and Johannes Glückler. 2019. "Alternative Economic Practices in Spanish Cities: From Grassroots Movements to Urban Policies? An Institutional Perspective." *European Planning Studies*: 1–20.

Sanz Merino, Noemí, and Daniela H Tarhuni Navarro. 2019. "Attitudes and Perceptions of Conacyt Researchers towards Public Communication of Science and Technology." *Public Understanding of Science* 28(1): 85–100.

Von Schomberg, Rene. 2011. Responsible Innovation. Managing the responsible emergence of science and innovation in society. *A Vision of Responsible Research*. ed. John Wiley.

Schreier, Margrit. 2012. *Qualitative Content Analysis in Practice*.

Schrögel, Philipp, and Alma Kolleck. 2018. "The Many Faces of Participation in Science." *Science & Technology Studies*: 77–99.

Schütz, Florian, Marie Lena Heidingsfelder, and Martina Schraudner. 2019. "Co-Shaping the Future in Quadruple Helix Innovation Systems: Uncovering Public Preferences toward Participatory Research and Innovation." *She Ji: The Journal of Design, Economics, and Innovation* 5(2): 128–46.

Seethaler, Sherry, John H. Evans, Cathy Gere, and Ramya M. Rajagopalan. 2019. "Science, Values, and Science Communication: Competencies for Pushing Beyond the Deficit Model." *Science Communication* 41(3): 378–88.

Serramia, Marc, Maite Lopez-Sanchez, Juan A. Rodríguez-Aguilar, and Patricio Escobar. 2019. "Optimising Participatory Budget Allocation: The Decidim Use Case." *Frontiers in Artificial Intelligence and Applications* 319: 193–202.

Sharon, Aviv J., and Ayelet Baram-Tsabari. 2014. "Measuring Mumbo Jumbo: A Preliminary Quantification of the Use of Jargon in Science Communication." *Public Understanding of Science* 23(5): 528–46.

Simis, Molly J., Haley Madden, Michael A. Cacciatore, and Sara K. Yeo. 2016. "The Lure of Rationality: Why Does the Deficit Model Persist in Science Communication?" *Public Understanding of Science* 25(4): 400–414.

Smallman, M. 2018. "Citizen Science and Responsible Research and Innovation." In *Citizen Science: Innovation in Open Science, Society and Policy*, ed. A. Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. & Bonn. London: UCL press, 241–53.

Smismans, Stijn. 2008. "New Modes of Governance and the Participatory Myth." *West European Politics* 31(5): 874–95.

Smith, Adrian, Mariano Fressoli, and Hernán Thomas. 2014. "Grassroots Innovation Movements: Challenges and Contributions." *Journal of Cleaner Production* 63: 114–24.

Smith, Graham. 2009. Democratic Innovations: Designing Institutions for Citizen Participation *Democratic Innovations: Designing Institutions for Citizen Participation*.

Smyth, Emma. 2001. "Would the Internet Widen Public Participation?: An Investigation Into Widening Participation in Leeds City Council's Community Plans." ed. University of Leeds.

Steen-Johnsen, Kari, Philippe Eynaud, and Filip Wijkström. 2011. "On Civil Society

Governance: An Emergent Research Field." *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations* 22(4): 555–65.

Stilgoe, Jack, Simon J. Lock, and James Wilsdon. 2014. "Why Should We Promote Public Engagement with Science?" *Public Understanding of Science* 23(1): 4–15.

Stilgoe, Jack, Richard Owen, and Phil Macnaghten. 2013. "Developing a Framework for Responsible Innovation." *Research Policy* 42(9): 1568–80.

Strasser, Bruno J. et al. 2018. "'Citizen Science'? Rethinking Science and Public Participation." *Science & Technology Studies* 32(2): 52–76.

Taminiau, Yvette. 2006. "Beyond Known Uncertainties: Interventions at the Fuel-Engine Interface." *Research Policy* 35(2): 247–65.

The Royal Society. 2006. *Survey of Factors Affecting Science Communication by Scientists and Engineers Excellence in Science.*

Torres-Albero, Cristóbal, M. Fernandez-Esquinas, Jesús Rey-Rocha, and M. J. Martin-Sempere. 2011. "Dissemination Practices in the Spanish Research System: Scientists Trapped in a Golden Cage." *Public Understanding of Science* 20(1): 12–25.

Torres-Albero, Cristóbal, Manuel Fernández-Esquinas, Jesús Rey-Rocha, and María José Martín-Sempere. 2011. "Dissemination Practices in the Spanish Research System: Scientists Trapped in a Golden Cage" eds. Martin W. Bauer and Pablo Jensen. *Public Understanding of Science* 20(1): 12–25.

Trench, Brian. 2006. "SCIENCE COMMUNICATION AND CITIZEN SCIENCE : HOW DEAD IS THE DEFICIT MODEL ? Brian Trench School of Communications Dublin City University Ireland." *9th International Conference on Public Communication of Science and Technology (PCST)* 9.

———. 2008. "Towards an Analytical Framework of Science Communication Models." In *Communicating Science in Social Contexts: New Models, New Practices*, Dordrecht: Springer Netherlands, 119–35.

United Nations. 2012. "Learning for the Future: Competences in Education for Sustainable Development." *Journal of Education for Sustainable Development* 6(1): 165–165.

Urbinati, Nadia, and Mark E. Warren. 2008. "The Concept of Representation in Contemporary Democratic Theory." *Annual Review of Political Science* 11(1): 387–412.

Värmland County Administrative Board. 2018. *A Quadruple Helix Guide for Innovations*. Sweden.

Vicente-Saez, Ruben, and Clara Martinez-Fuentes. 2018. "Open Science Now: A

Systematic Literature Review for an Integrated Definition." *Journal of Business Research* 88: 428–36.

Visser, Anna. 2018. "From Participation to Deliberation: A Critical Genealogy of Deliberative Democracy." *Irish Political Studies* 33(3): 430–32.

Volodin, Dmytro. 2019. "Deliberative Democracy and Trust in Political Institutions at the Local Level: Evidence from Participatory Budgeting Experiment in Ukraine." *Contemporary Politics* 25(1): 78–93.

Watermeyer, R. 2012. "Measuring the Impact Values of Public Engagement in Medical Contexts." *Science Communication* 34(6): 752–75.

Weil, Frederick D., Heather M. Rackin, and David Maddox. 2018. "Collective Resources in the Repopulation of New Orleans after Hurricane Katrina." *Natural Hazards* 94(2): 927–52.

Welp, Martin, Anne de la Vega-Leinert, Susanne Stoll-Kleemann, and Carlo C. Jaeger. 2006. "Science-Based Stakeholder Dialogues: Theories and Tools." *Global Environmental Change* 16(2): 170–81.

Wiedemann, Peter M., and Susanne Femers. 1993. "Public Participation in Waste Management Decision Making: Analysis and Management of Conflicts." *Journal of Hazardous Materials* 33(3): 355–68.

Woelfle, Michael et al. 2011. "Open Science Is a Research Accelerator." *Nature Chemistry* 3(10): 745–48.

Wylie, A. 2015. "A Plurality of Pluralisms: Collaborative Practice in Archaeology." In *Objectivity in Science: New Perspectives from Science and Technology Studies*, eds. Flavia Padovani, Alan Richardson, and Jonathan Y. Tsou. Berlin: Springer, 189–210.

Xu, Bo, and Dahui Li. 2015. "An Empirical Study of the Motivations for Content Contribution and Community Participation in Wikipedia." *Information & Management* 52(3): 275–86.