Grant Agreement No 960366
Project Acronym: *ISEED*
Project Title: *Inclusive Science and European Democracies*
Project website: www.iseedeurope.eu
Framework Programme H2020
Call H2020-SC6-GOVERNANCE-d under the H2020 programme

Milestone 5

-

WP2

Bibliographical survey

of participative science programmes done

Task leader for this milestone: **UNIVE** (Elena Denia)

Documents status		
Revision	Date	Description
V1.0	31/08/2021	final document

Acknowledgements and disclaimer

The ISEED project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 960366.

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[…] the rapid growth of citizen science presents many examples where the challenges of democratization, the needs of science education, and the affordances of science communication have come together. Citizen scientists are learning science at the same time they are challenging scientific orthodoxies and making claims on the governance of science.

Can we understand citizen science? Bruce Lewenstein (2016:2).

1. INTRODUCTION

The social appropriation by citizens of the processes of production of science and technology is an issue that has acquired relevance in recent decades in a context in which the accelerated growth of such techno-science has not only transformed the lives of citizens with a torrent of goods and services never seen before, but has also changed the way in which they approach the world in such a way that "the factors that in the past were considered to be the cause of the advancement of societies —the great intellectuals or the influence of economic agents on social classes— are being supplanted by the emergence of new technologies, are being supplanted as the driving force of social evolution. The new engine is, precisely, science" (Watson, 2002: 11). On the other hand, the possible undesirable consequences of certain scientific developments increasingly produce public manifestations of ambivalence, criticism and mistrust, shifting the scientific debate to the realm of public controversy, and today amplified by the "network society" (Castells, 2001).

For this reason, the debate on the role of citizens in democratic societies, both in decision-making in science and in the practice of science itself, has been the subject of numerous theoretical reflections from the fields of the philosophy of science, sociology of science, political theory and Science & Technology Studies (STS).

On the one hand, the theoretical proposals would be centred on dialogue concerning both the functioning of research groups and even the configuration of political research agendas, with some of the questions raised being: who decides what is researched and how many resources are allocated for a given purpose? How should the urgency of research programmes be evaluated? What disputes require public debate and a search for consensus? We would find here theoretical proposals anchored in the strengthening of deliberative democracy such as, for example, the meetings between informed citizens proposed by Kitcher (2011), Habermas' deliberative surveys (Habermas, {1992} 2010), or the "participatory turn" proposed by Jasanoff (2003). All of these can be grouped under the term "public engagement" which, as will be seen throughout this report, has not only given rise to numerous theorisations, but has also been the subject of institutional declarations —see the European Commission's policy (Macq, 2020; European Commission; 2002; 2008; 2014)— and practical experiences that aim to make science more robust and socially responsible (Gibbons, 1999; Callon, 1999). In this context of public participation in science, the term "citizen science" appears understood as a form of public engagement, and first promoted by social scientists Alan Irwin (1995).

On the other hand, citizen science umbrella also embraces the interpretation of public participation, to a greater or lesser extent, in the production of science, generating knowledge while at the same time learning about the processes of scientific research —for many, a win-win situation—, which may or may not involve aspects of public engagement (Riesch & Potter, 2014). This meaning of the term is initially used by Rick Bonney and other American scientists (Bonney et al., 2009), and being an emerging field of research in recent years, still requires further theorisation in aspects such as audience selection, characterisation of motivations, impact assessment, or, of particular interest to this report, the elements of deliberative democracy that may be present in citizen science projects.

In this report, firstly, it has been carried out an account of the evolution of the conceptualization of science audiences from its consideration as a passive entity to the current concept of co-governance of science through public engagement, based mainly on the need to strengthen participatory democracy. This is considered necessary to address, secondly, the academic literature on the conceptualization of citizen science and its practice, because without these prior considerations we would lack the necessary tools to deepen the analysis of a term, which like so many others in the fields of study of the relationship between science and society, is plagued by a conceptual ambiguity that makes its analysis extremely difficult.

2. CONTEXT FOR CITIZEN SCIENCE

2.1. Science audiences: towards a model of participation

The origin of modern science is usually dated to the Copernican revolution, following the publication in 1543 of Nicolaus Copernicus' book *De Revolutionibus*. From the Renaissance onwards, with the invention of the printing press and the generalisation use of vernacular languages, science became increasingly widespread among the enlightened public, and confidence in its methods grew rapidly thanks to the contributions of Galileo, Kepler, Boyle and in particular Isaac Newton (1643-1727), whose theories gained great popularity and acceptance, and even spread in several languages, largely thanks to the publication of the first popular science books. In this way, the conception of science was taking shape in society, its presence accelerating with the French Revolution (1789) and the ideals of the French Enlightenment with its exaltation of reason and progress, and above all with the Industrial Revolution —initiated in the last years of the 18th century with the invention of the steam engine— whose applications would henceforth provide citizens with an unprecedented torrent of goods and services.

The resounding success of the scientific endeavor earns, in the following decades, the confidence of a public that, although it does not understand the theoretical assumptions underlying its achievements, strongly supports it because of the material progress that derives from it. In particular, the popularization of science experienced an unstoppable rise throughout Europe in the nineteenth century, reaching its apogee in the second half through literary pieces, public lectures, press, museums and universal exhibitions, among other formats, which also served the research of the scientists themselves.

This period saw the beginning of two trends that can be traced back to the present day. On the one hand, Victorian England was characterized, especially in the first half of the 19th century[1], by the promotion of *amateur* science, within the framework of the republic of science in which both laypeople and scientists had a place. The group formed by these *amateurs*, with varying degrees of dedication, was one more among the scientific community as a whole[2]. In contrast, the French conception of the public as a passive entity to be enlightened, lasted for much of the 20th century, framed in the so-called deficit model (see below 2.1.i).

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[1] It should be noted that, at that time, the distinction between science and natural philosophy was still blurred. It was in 1833 that the thinker William Whewell coined the term "scientist" to designate "natural philosophers" (Encyclopædia Britannica, 1911). He conceived scientific progress through the analogy of a river and its affluents, imagining that discoveries converge and thus evoking an image of science as the result of a unification. On the other hand, already at the beginning of the same century, the founder of positive philosophy, Auguste Comte, had tried to find a precise definition to demarcate science from the non-scientific, an initiative that proved unsuccessful. In fact, even today, we still do not have a clear criterion to establish the distinction.
In this way, it is possible to trace how the conception of science changes when the so-called "natural philosophers" begin to apply mathematics to the study of the material world and to elaborate a set of rules that define the "scientific method" —such as experimentation, hypothesis testing or reproducibility—.

[2] It is not unreasonable to draw parallels with the current *engagement* movements (see section 3.2.) that have arisen in the Anglo-Saxon world.

It is from the second half of the nineteenth century when the term "scientist" is used to designate the science professional who follows certain guidelines, and who works under a modern conception of science whose objectives would be to understand, explain, predict and dominate the world, applying mathematics and elaborating a set of rules that define the "scientific method" —such as experimentation, hypothesis testing or reproducibility—. At the same time, the scientific institution takes shape as a decentralized, competitive and dogmatic academic system (Latour, 1999). Thus:

> Science, in the first half of the nineteenth century as in previous centuries, was part of the intellectual culture of mankind, into which all might enter and from which all might profit. But from 1860 onwards it becomes more of a closed shop, with its own puritan ethic, from which amateurs are more and more excluded. (Lucas, 1979: 330)

With the techno-scientific explosion of the 20th century and the increase in literacy, the popularization of science gained strength, reaching a wider public and even producing phenomena such as those of the star scientists persecuted by the media —such as Albert Einstein or Marie—. However, as the intellectual products of science become increasingly abstract, the gap between scientists —perceived as abstracted from the world in their ivory tower— and the public widens, thus weakening the trust deposited in science and giving rise, in the second half of the century, to issues such as the danger of atomic energy or environmental issues that gave rise to discordant voices about the benefits of science. This, together with the fact that the State, as a financing entity, began to take part in research programs, motivated a new social role for the scientist. Since then, scientific work is developed not only for scientific reasons, but also for political reasons.

One of the first to formulate the idea that there is a gap between science and society that must be bridged was the philosopher John Dewey, in an article in which he emphasized that scientists have a moral obligation to transmit science to the lay public and to foster the "scientific attitude" —including knowledge of the methods of science— (Dewey, 1934). This reflection was the trigger in the United States for the first questionnaires launched by some teachers to measure science knowledge in students at different educational levels, carrying out local surveys (Miller, 1983).

From these studies, theoretical reflections on the desirable relationship between science and citizenship and the role that each party should assume arose in the 1980s, reaching a multidisciplinary character that encompasses, in addition to initiatives to improve the scientific literacy of citizens, also studies of public perception, understanding and participation in science. In particular, the two theoretical models, proposed from the sociology of science, that trace the relationship between science and citizenship are the "deficit model" and, later, the "contextual model".

(i) A lack of knowledge

Formulated in the second half of the 20th century, the concept of deficit in this context refers to a lack of information in the public, understood in turn as a passive entity with gaps in knowledge that can and *should* be filled (Durant et al., 1992)[3]. Scientific knowledge thus flows in a unidirectional way, from the scientific authority to the citizens, and it is presumed that the lack of social support for science is due to educational deficiencies. In this sense, the model responds to

[3] Other labels associated with the deficit model: Public Appreciation of Science and Technology (PAST); scientific literacy model (Brossard and Lewenstein, 2010; Väliverronen, 1993); dissemination/dissemination model (Horst, 2008); dominant approach (Myers, 2003; Hilgartner, 1990) or canonical approach to science popularization (Grundmann and Cavaillé, 2000; Bucchi, 1998).

science promotion policies to improve funding and the image of science held by the public —aspects that are linked to each other–, and for such purposes scientific literacy strategies are implemented. It should be noted that, among the different nuances of the term "scientific literacy", the one that has received most attention among academics is the civic or political one:

> The aim of civic science literacy is precisely to enable the citizen to become more aware of science and science-related issues so that he and his representatives would not shy may from bringing their common sense to bear upon such issues and thus participate more fully in the democratic processes of an increasingly technological society. It is not sufficient to leave decisions on science-related issues to experts […]. (Shen, 1975: 48).

Here the question arises as to what level of understanding is necessary for citizens to understand and participate in public policy debates involving aspects of science and technology based on the available scientific evidence, especially those that are the subject of controversy. However, although most authors argue that reaching a certain minimum level is indispensable for decision-making in democratic societies (Thomas & Durant, 1987), defining this "minimum level" has been and continues to be the subject of unfinished debate.

In particular, surveys of the social perception of science emerged in the middle of the last century to try to quantify the scientific literacy of the population and to take concrete measures to increase it. Within these efforts, the aim is to measure interest, knowledge, information sources and attitudes. After initially detecting a low level of scientific literacy in the U.S. population (Davies, 1958), the State assumed responsibility for implementing strategies to mitigate it. For decades, the prevailing theoretical assumption was that favorable attitudes towards science depended on the degree of knowledge about it, and the following slogan was assumed: the more you know about science, the more you like it. These surveys have been systematized since 1970 and over the years different theoretical frameworks have been proposed to analyze and interpret them.

To understand the context of large-scale surveys, a key work in the specialized literature is the review of reference articles on the field by Bauer, Allum & Miller (2007), in which three consecutive paradigms are identified to frame studies of social perception of science over time: Scientific literacy (SL) (1960-1985); Public Understanding of Science (PUS) (1985-mid 1990s); Science in Society (mid-1990s onwards). Each paradigm responds to a specific approach and concerns located in a specific time frame. Thus, each of the three diagnoses in a different way the tensions that arise in the science-society interaction and proposes specific strategies to attenuate the gap between the two. The first two are framed within the deficit model. The third, as shown below, is framed within the contextual model.

In the first paradigm identified, Scientific Literacy, the key element is "knowledge" and the strategy for action on the part of public authorities is to promote science education, this being the mechanism for creating an informed society that will ultimately lead to a more effective political class. In contrast, in the second paradigm, Public Understanding of Science, scientific institutions express their concern about a public that does not show sufficient support for science, and furthermore, about anti-science audiences. In this case, the weight lies not only in the mechanism of formal education, but also in science communication practices[4]. That is, the strategies proposed to meet the challenge are, in addition to educating the public as a starting point, to seduce it; with the aim of changing negative attitudes. In fact, even "Scientists must learn to communicate with the public, be willing to do so, and indeed consider it their duty to do so" (Royal Society, 1985: 6).

[4] The report *The Public Understanding of Science* contains a series of recommendations addressed to different agents, including the scientific community, the educational system, the mass media, industry, government and museums. (Royal Society, 1985).

Accordingly, since the 1990s, governments, institutions and international organizations have begun to implement public policies to finance the promotion of scientific culture beyond the educational sphere.

The deficit model certainly serves to justify the political objectives of promoting science, aimed both at winning public favor —a public that provides “silent support” (Bodmer, 2010: 157) and is more caring and enthusiastic (Sturgis & Allum, 2004)—, and at generating vocations and promoting the use of new technologies in increasingly innovative societies. Strategies to achieve this would include formal education and science communication.

However, this is a position that has not only been described as condescending (Royal Society, 1985), but subsequent interpretations of the results of surveys of public perception of science have questioned the underlying assumptions. Numerous authors have been critical of the idea that lack of knowledge is responsible for negative attitudes toward science and that, therefore, instructing citizens should be sufficient for a public with such deficiencies (Sturgis & Allum, 2004). Moreover, it has been disputed on numerous occasions that support for science is a response to a deep understanding of science. On the contrary, an individual may exhibit enthusiasm for science even when his or her knowledge levels are low (Bauer, 2009; 2012). Further, deeper analyses of the data have shown that having more knowledge can contribute to holding a critical attitude towards science, and that, in particular, awareness of the risks associated with science leads to more critical attitudes (Bauer, 2012). Thus, a citizen who believes in the benefits of science may also have reservations about its impact (Miller, 2004)[5].

It should be noted that there are authors who do not completely dismiss the deficit model, despite considering it insufficient, and do not find pernicious the intention of obtaining quantitative data to estimate what proportion of individuals possess certain knowledge about science among the population (Pardo, 2014). In fact, there is no reason to suppose that scientific knowledge does not have an additional and independent effect in relation to the public trust in science, an aspect that may influence the attitudes exhibited by citizens —in addition to others, such as economic or political ones— (Sturgis & Allum, 2004). In any case, whether or not knowledge deficiency is an explanation for attitudes towards science, there may still be a knowledge deficit in the lay public that it is considered desirable to mitigate (Miller, 2001).

In general, there is consensus that, beyond interpreting the situation in terms of public ignorance or scientific illiteracy, contextual factors should be considered (Ziman, 1991), since the understanding of science depends on a variety of them (Irwin & Wynne, 1996; Gregory & Miller, 1998).

(ii) Contextual model

The contextual model emerged in the 1990s with the purpose of offering a different view of the relationship between science and the public than the previous model, including the social and institutional dimension of the scientific experience, the public's responses to it, and the representations that scientists themselves have of their audiences (Miller, 1998). Its origin is probably to be found in a study of expert-public relations during the controversy over the radioactive waste rain that affected the region of Cumbria, northwest England, after the explosion of the Chernobyl nuclear power plant, according to which the technicians' disregard for the practical knowledge of those affected generated serious economic losses among farmers and

[5] It has been further pointed out that "this model misrepresents science itself by portraying it as an unproblematic body of knowledge” (Durant et al., 1992: 162).

brought the scientific advisors into discredit (Wynne, 1992). The model also implies the re-examination of the categories of "expert" and " layperson" (Cortassa, 2010).

Unlike the deficit model, citizens are not seen as empty containers but are pragmatically interested in issues that concern them (Alcíbar, 2015), and learn best about those topics that have meaning in their personal lives (Brossard & Lewenstein, 2010). Note that, in this sense, individuals relate to science socially, not abstractly.

Associated with the contextual model, the core of the third paradigm, *Science in Society*, is defined by a deficit of mutual trust that works in both directions: in addition to contemplating a lack of knowledge and trust linked to the public, a deficiency is detected in scientific institutions and experts that manifests itself through prejudices towards an "ignorant public" (House of Lords, 2000). A crisis of trust is thus evoked, and efforts are directed towards the search for commitment, both on the side of the public and of the institutions, encouraging deliberation and public participation to rebuild this eroded trust (Bauer, 2009). Increasing the level of understanding of science among the public is no longer the only objective, but rather a climate of commitment based on dialogue between the public and the scientific community that overcomes the unidirectional and asymmetrical relationship of the previous stage. These reflections crystallize, from the 21st century onwards, in that new approach that will make its way into the political agendas of Western societies, acquiring greater prominence in the present century, the so-called *engagement*: a plea to involve the different social agents —politicians, scientists and citizens— in the dialogue on science. This strategy (see section 3.2.) focuses, on the one hand, on public participation in science, and on the other, on the commitment of the scientific community and institutions to citizens.

To summarize, throughout the course of the three paradigms, there is a change in the understanding of the public, and it becomes clear that "Like other relationships, science–society is not just a matter of distance, but also one of quality" (Bauer, 2009: 238). Table 1 provides an overview of the paradigms as a chronological marker of the political concerns of each phase in which, by attributing a particular deficit, specific forms of intervention are proposed. It should be noted that while each paradigm exhibits a distinct emphasis on promoting policy strategies to mitigate the gap between science and society, the paradigms sometimes overlap —broadly speaking, at each point in time one has more preeminence than the others—.

Paradigm	Conceptualization	Deficit	Strategy
Scientific Literacy	Level of knowledge.	Scientific knowledge.	Education.
Public Understanding of Science	Level of knowledge. Attitudinal concerns.	Knowledge, attitudes, and trust towards science.	Education. Communication (promotion of dissemination).
Science in Society	Concern for attitudes. Participation.	Trust (in both directions: from the public and from the institutions).	Education. Communication. Engagement (participation and promotion of dialogue to enhance the social voice).

2.2. The participatory turn

(i) Participation in the light of democracy

The concept of *participatory democracy* —a conception of democracy put forward in the US in the 1960s—, responds to a declared willingness of civil society to contribute to decision-making (Rogers, 2006) and constitutes a measure for mediation between civil society and political institutions in the absence of consensus (Hilmer, 2010), through which the public is able to influence political decisions that affect individual and collective interests (Baum, 2015) —ideally in conditions of equality (Pateman, 1970)—. It has been suggested that public participation is a democratic right of citizenship (Liston, 2019). In particular, *deliberative democracy* —coined by (Bessette, 1980)— is based on public dialogue for collective decision making; from the "mini publics" (Urbinati and Warren 2008) to more inclusive proposals through open deliberations (Davies et al., 2012). For example, through consensus conferences, citizen panels, or other spaces for debate.

This debate has subsequently intensified and there has been talk of a "third wave of democratization" (Wampler, 2012: 666), giving rise to theorizations around the construction of a model of participatory democracy that, without claiming to replace representative democracy, seeks to increase the legitimacy of the latter (Michels, 2011) by giving voice to the citizenship through certain democratic innovations —such as consensus conferences, deliberative opinion polls, electronic voting, etc. An analysis of more than 50 practices can be found in Smith (2005).

Among these theorizations, the philosopher Jürgen Habermas stands out, developing an idea of "deliberative democracy" for which one of its presuppositions is the concept of "public sphere", understood as a broad, inclusive, spontaneous and plural space that plays a mediating role between the political system and civil society, and which includes the institutionalized discourses of politicians, as well as the opinions of the media and civil society. For Habermas, independent public forums constitute the basis of popular sovereignty (Habermas, {1992} 2010). This public sphere is an open network formed in turn by sub-spheres that overlap each other with fuzzy boundaries; although they are shaped by a central topic such as art, religion, science or cinema, among others.

Of course, science is no exception (Godden, 2017) and, from the second half of the twentieth century, crystallize both an activist trend that demands greater direct participation in its production and a series of theoretical formulations that understand that the participation of citizens contributes to the social appropriation of knowledge and its empowerment.

This postulates the emergence of a new "social contract" between science and society that would replace the social contract established after World War II, according to which the State provides funding and scientists, exercising in a responsible and autonomous manner, return knowledge and technological developments[6]. On this, Gibbons (1999) clarifies that:

[6] The need to articulate science and politics was triggered mainly by the legacy of the two world wars, which involved massive state intervention to cover scientific objectives with a military orientation, in a model of scientific praxis involving large teams and high budgets, the so-called Big Science (De Solla Price, 1963). Of special influence was the proposal of Vannevar Bush, an engineer at the Massachusetts Institute of Technology (MIT) and presidential advisor, who wrote his famous report *Science, the Endless Frontier* (Bush, 1945), which responds to an analogy with the social contract of political theory, based on giving freedom in exchange for security (Locke; Hobbes).

> A new social contract will therefore involve a dynamic process in which the authority of science will need to be legitimated again and again. To maintain this, science must enter the agora and participate fully in the production of socially robust knowledge. (Gibbons, 1999: 84).

In civil society, movements such as "citizen scientist" organizations, which emerged in response to the Manhattan Project and the nuclear race, were initially led by elite scientists and gradually attracted broad sectors of society. They were later joined by other movements such as environmentalists and patients' associations (AIDS, etc.), all of which questioned the quality of representative democracies —in which citizens are limited to exercising their vote from time to time— and demanded new forms of politics, calling for public spaces where citizens could debate the decisions that affect them. With the maturation of these movements in the last decades of the 20th century and their success in placing science and technology as a matter of social debate, they contributed to the establishment of a new stage characterized by public participation in certain activities including advice, evaluation or discussion of research agendas and approaches (Invernizzi, 2004).

There is thus talk of a democratic strengthening of society and, in fact, this is demonstrated by various experiences showing the influence of public attitudes towards science on policy-making - for example, changes in scientific policies regarding GMO's (Berg & Lidskog 2018); changes in the price of antiretrovirals (Kapstein & Busby, 2016); or the media phenomenon Greta Thunberg (Fisher, 2019).

In the specialized literature, initially catch the attention the hybrid forums described by Callon (1999), which some authors call "collaborative co-production of knowledge". These are associations or foundations linked to a particular group —for example, patient forums— in which relevant information, proposals, initiatives and demands circulate that not only guide and enrich research in a given field but also help participants to better understand the complexity of the problems and develop skills that bring them closer to the experts (Epstein, 1995).

These new approaches to the conception of science and its relationship with the public have given rise to numerous theoretical works guided by the desire to incorporate the social voice into the practice of science, advocating a co-construction of science and society, and promoting concepts such as “socially robust science” and legitimizing hybrid research practices (Callon, 1999; Callon, Lascoumes, & Barthe, 2002). One thus speaks of a "participatory turn" (Jasanoff, 2003). In addition:

> The question confronting the governance of science is how to bring knowledgeable publics into the front-end of scientific and technological production – a place from which they have historically been strictly excluded. (Jasanoff, 2003: 235).

It is thus considered that participatory processes are intended to improve the quality of decision-making and create more socially solid scientific and technological solutions and that citizens should be seen as subjects of the process who actively work to shape decisions, rather than just having their opinions surveyed by other actors (Fiorino, 1989; Stirling, 2008; Wilsdon & Willis, 2004).

In this sense, many advocate that the interaction between scientists and laypeople should take place in a public space for open and democratic forms of reasoning and decision making in what some call "agora" (Nowotny, Scott & Gibbons; 2001; 2003). According to the formulation of these authors, traditional disciplinary science would have been replaced for the most part by a new mode of knowledge production, the so-called "Mode 2" characterized by:

I. All science is, to some extent, "applied" science.
II. Science is increasingly transdisciplinary.
III. Knowledge is generated in a wider variety of places than ever before: universities, industry, consultancies, think tanks, among others.
IV. Participants in science have become more aware of the social implications of their work, and audiences have become more aware of the ways in which science and technology affect their interests and values.
V. Scientific research is more socially integrated and seeks more robust forms of knowledge production.
VI. Interaction between scientists and laypeople takes place in a public space for open and democratic forms of reasoning and decision making in what can be called the "agora".

To integrate citizen participation in setting research goals, Kitcher (2011) proposes a system consisting of a "well-informed" representative body of society that receives advice and can deliberate collectively in decision-making. In particular, through a mixed group of scientific and political experts who advise and recommend, discuss and evaluate, and thus decisions rest with both. Note that the direct participation of all citizens is not proposed here, but to find an adequate representativeness.

At the institutional level, programmatic documents have been issued and actions designed to promote participation in recent decades. An illustrative example is the OECD's handbook on public policy making *Citizens as Partners: Handbook on Information, Consultation and Public Participation in Policy-Making* (Gramberger, 2006). And specifically science-oriented, the adoption in 2003 of the statement "involving the public in science" as the slogan of the American Association for the Advancement of Science (AAAS) in the United States; and within the European framework, the participatory approaches of the European Commission (EC), since participacion became one of the central issues of the Lisbon strategy for the "European knowledge society", launched in 2000, and which has subsequently developed the *Science with and for Society* program (European Commission, 2014a) and has issued relevant reports such as *Public Engagement in Science* (European Commission, 2008). In particular, it is worth highlighting the strategies advocated by the EC that respond to this participatory turn:

I. Responsible research and innovation (RRI): where «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» (European Commission, 2014b), and for which there is a shared responsibility on scientific production among societal actors and innovators and its governance (Von Schomberg, 2013). Stilgoe et al. (2013) speak of anticipation, reflexivity, inclusion and responsiveness.
II. Open science: (European Commission, 2020): which includes the use of new digital technologies that enable collaboration and knowledge dissemination (Gallagher et al., 2019) and covers all the stages of the research process: open data, open source, methodology, education, access, open peer review. In this sense, scientific knowledge belongs to the community insofar as it is a product of it (Fecher & Friesike, 2014).

III. The Quadruple helix model of innovation based on Lindberg et al. (2014) within the innovation system, which includes one more dimension concerning civil society, in addition to the remaining three of the triple helix model —academia, public sector, industry—. In any case citizens are an active part (Schütz, Heidingsfelder, & Schraudner, 2019), and in fact, for some they become the main actor (Carayannis & Campbell, 2009).

Notwithstanding the above, it should be noted that the European Commission itself recognizes that the various forms of deliberative activities designed to involve the public in scientific development have serious limitations.

> Dialogue tends to be restricted to particular questions, posed at particular stages in the cycle of research, development and exploitation. Possible risks are endlessly debated, while deeper questions about the values, visions, and vested interests that motivate scientific endeavour often remain unasked or unanswered. (European Commission, 2008: 16).

(ii) Engagement

Without prejudice to the fact that forms of engagement can be traced back to earlier periods, we can consider that engagement experiences, understood in the current sense, began with a limited scope between the 1960s and 1980s. Some examples would be the first science shops, created by Dutch and German universities in the 1960s; the consensus conferences of the mid-1970s in the United States; or the citizen juries or the Danish Board of Technology established in Denmark in 1986 to advise the Danish Parliament (Invernizzi, 2004).

Differentially, the 1980s saw a series of tragic events such as the Bhopal chemical disaster (1984) or the accident at the Chernobyl nuclear power plant (1986), together with health emergencies such as the AIDS pandemic or the bovine spongiform encephalopathy crisis in the United Kingdom (1989). This, together with a series of scientific malpractice scandals, led to an increase in public awareness of the risks associated with science and technology, and prompted both reactions from public institutions and an increase in social activism[7]. In this way, throughout the 1980s and 1990s, concerned citizens developed new forms of bottom-up public inclusion. Examples were AIDS activists in the United States, who gained representation on advisory committees and hospital boards as well as research centers (Epstein, 1995); the Association Francaise contre les Myopathies (AFM), which intervened in medical research and promoted social recognition of patients (Callon & Rabeharisoa, 2008); or the action of the residents of Woburn (Massachusetts) to collect epidemiological data and information on a suspiciously high number of cases of childhood leukemia in their area, which motivated a research program at MIT that discovered genetic mutations caused by trichloroethylene present in the waters of the area (Phil Brown & Mikkelsen, 1997).

It has also been suggested that engagement was born from the intersection between top down initiatives —from managers of institutions to incorporate the voices of users in the evaluation of research proposals and in the determination of priorities in the distribution of public funding—; and a variety of bottom up local movements, research demands coming from diverse social groups —a phenomenon known as "community-based research" that directly influences the scientific agenda and technological innovation—. For civil society associations and concerned

[7] Another example recently studied is the "Vajont disaster" in Italy in the 1960s (Barrotta & Montuschi, 2018a). Barrotta & Montuschi (2018b) argue that this catastrophe is a clear manifestation that expert scientific knowledge is inadequate when it is not integrated with local knowledge.

citizens, this would be a way of influencing research agendas and technological choices inspired by democratic ideals (Bensaude Vincent, 2014; Invernizzi, 2004).

It is in the 1990s and, in particular, when citizen participation in science and technology became a topic of growing academic and social importance, extending to different developed countries and being attached to disparate fields such as telecommunications, genetic engineering, climate change research or nanotechnology. In this way, it can be considered a new movement that is institutionally supported by various organizations and even recognized in traditional scientific publications such as *Nature*, which devoted a special issue to it in 2001.

Also from the institutional point of view, it should be noted that the European Union (EU), through the European Commission (EC), has played an increasingly important role in promoting participatory approaches, starting with the so-called *Science and Society Action Plan* (European Commission, 2002) and continuing with the subsequent Sixth and Seventh Framework Programs and their successors, the *Horizon 2020* program, and the current Horizon Europe (HE), so that in the last twenty years issues relating to the interweaving of science and society have been increasingly introduced in all thematic areas of European policies; both in terms of the content of science and research and the exploitation and accessibility of their results. Accordingly, the seminal programmatic report *Public Engagement in Science* (European Commission, 2008), states:

> […] public engagement is not simply about better communication. Institutions need to provide meaningful opportunities for public voices to influence decision-making. They need to ask how effectively the changing values, hopes and aspirations of society are being incorporated into the products and trajectories of science and technology. (European Commission, 2008: 15).

The transition sought is, on the one hand, that lay people go from being passive consumers to concerned citizens, and on the other hand, that scientists dedicate time to the social and ethical dimensions of their work. To this end, it is proposed to develop scientists' capacities to engage with the public and the search for ways to incentivize them, and to incorporate society in the early stages of the scientific research process by recognizing the contribution of public knowledge and coining the label "responsible research and innovation" (RRI), understood as "an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation" (European Commission, 2014b: link)[8].

Focusing on the conceptualization of science engagement, it should be noted that it does not have a universally accepted definition, beyond the fact that its key is dialogue. It can be understood as the participation and deliberation of the public in science and technology issues, and seeks to employ diverse organizational and institutional mechanisms, such as consensus conferences, referendums, participation of public representatives in panels, deliberative polls, among other examples. Thus, the question as to what activities constitute it is open, being the general opinion that it encompasses any formula —including online technologies— that involves debate and mutual learning between the scientific community and the lay public.

Despite all this, such a participatory turn has received numerous criticisms from the academic field with distinguished authors such as Irwin (2014), Jasanoff (2014) or Wynne (2014) criticizing the persistence of the linear model of communication. In particular, they call for further reflection on the potential and limitations of "sponsored" participatory practices, pointing to unresolved questions that future debates on participatory approaches will have to confront. For

[8] In particular, RRI was structured in the following six dimensions: governance, ethics, gender equality, open access, citizen participation and science education; each of them giving rise to different actions and projects. (European Commission, 2014b).

example, whether they are sufficiently democratic, whether audience selection is sufficiently random, how to approach audiences not interested in science, and similar questions. In particular, a central question that emerges in this regard is: are these exercises sufficient or should we devise a more comprehensive model of engagement in line with the democratic society?

On the other hand, it should be noted that the concept of "public understanding of science" still has followers in academia who consider that the new approach suffers from conceptual weaknesses and offers modest results in practice. Thus, Pardo (2014) considers that "from an analytical point of view, the engagement approach does not represent a real conceptual gain with respect to the deficit and scientific literacy model" (Pardo, 2014: 59), and that the "forms of participation tested hardly allow the integration of the public of mass societies, it not being evident that their "voice" can be represented by twenty or thirty people, however well chosen they may have been" (Pardo, 2001: 58-59). For the author, many of these exercises seek that the "attentive public"[9] —coined by Miller (1983)— make the vision of the scientific community on controversial areas their own.

Finally, perhaps a more nuanced view is that of Davies (2013), who considers that while it is easy to point out the shortcomings of the triumphalist story of the shift from Public Understanding of Science (PUS) to Public Engagement in Science & Technology (PEST), on the contrary, once the experiences of public engagement of scientists and communication professionals are explored, they should be evaluated not only in terms of their positive outcomes for the promotion of democracy but also for their capacity to increase mutual enjoyment and learning. In this sense the author argues for the coexistence of different models of communication and asks: “Are there ways of understanding the practice and meaning of public engagement that can cope with this multiplicity and that do not force us to distinguish simply between PUS and PEST, old and new, outdated and enlightened?” (Sarah R. Davies, 2013: 690).

[9] Public interested and informed about new discoveries, inventions and technologies.

3. CITIZEN SCIENCE: CONCEPT AND PRACTICE

There are differences in interpretations of what citizen science is. On the one hand, in Irwin's tradition (Irwin, 1995) sociologists refer to "citizen science" as two-way public dialogue to give voice to the laity and increase democratic quality, which coincides with the concept of engagement linked to deliberative democracy. In this sense, Irwin (1995) pointed out that citizen science responds to the needs and concerns of citizens. On the other hand, followers of the American approach opt for a more practical perspective with functional definitions, centered on projects in which engagement figures among their objectives to a greater or lesser extent; being greater in the so-called co-created projects, in which participants collaborate in all stages of the scientific project, than in the collaborative ones, whose participants help in data analysis and dissemination —and occasionally in the design of the study—, or in the merely contributive ones, in which participants are mainly engaged in data collection (Senabre et al., 2018). In these cases, research projects that were previously reserved for the academic world open up to the general public, and align them around common challenges. One may then ask: Is the ultimate goal of citizen science to add knowledge to a scientific discipline and produce science? Or to involve it in the whole scientific process —which includes, among other things, the elaboration of research agendas?

> […] most participatory projects in science and research can be traced back to two main paradigms: the public participates either in a dialogue about science (governance) or in doing science in its diverse forms. We use the term dialogic formats to cover all types of consultations and public discussions, e.g. about nuclear waste management or about potential benefits and risks of genetically modified organisms. The doing-science-together approaches invite citizens to take part in the process of generating knowledge. (Schrögel & Kolleck, 2018: 3).

Broadly speaking, citizen science encompasses a variety of ways in which society is involved in science, and its outcomes range from knowledge production to political change. Some conceptualizations have thus been proposed that take into account the political side —see, for example, Haklay (2018); Árnason (2013) or Irwin (2001); and the dilemmas presented by citizen participation in science policy highlighted by Rowe & Watermeyer (2018)—; while others have focused on the process of co-construction of knowledge —(Bonney et al., 2009; Shirk et al. 2012; Stilgoe, Lock, and Wilsdon 2014)—. Despite the distinction between the two streams, it has been argued that a citizen science project can incorporate both: knowledge generation and political influence. One way to exemplify this may be to repair that lessons learned from specific projects are an opportunity to increase citizen awareness and action (Campbell et al., 2019).

In the institutional arena, in fact, hybrid conceptualizations of citizen science are common. This is reflected in the reference document *Green Paper on Citizen Science: Citizen Science for Europe* (2014), elaborated in the context of the *Socientize Project* (2012-2014) and funded by the European Commission, where it was pointed out that:

> Citizen Science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture. […] As a

> result of this open, networked and trans-disciplinary scenario, science-society-policy interactions are improved leading to a more democratic research based on evidence-informed decision making. (Socientize Consortium, 2013: 6).

This document exhibited a European vision of citizen science in which the results of these practices are advocated to be included in decision-making processes (Bonn et al., 2016: 10). It should be noted, however, that there have been changes in the European conception of how citizenship should be involved in science. While a political discourse on the value of participation has emerged in Europe since the early 1990s, and various mechanisms for participation in science policy have been created and promoted, three discursive shifts can be identified (Macq et al., 2020):

> Policies about participation in science and technology underwent three main phases. The initial phase is characterized by the development of a discourse on participation framed as deliberation for science and technology policymaking (2000–2010). The second phase is a transitional phase, integrating the growing emphasis on innovation (2010–2014). The third sees the emergence of a discourse on participation in production of knowledge and innovation (2014-today). (Macq et al., 2020: 492-493).

From a broader perspective, for some, an approach to understanding the rationale for all these efforts lies in the active inclusion of citizens in scientific culture: "to think about science in culture, rather than science as an autonomous culture" (Kaiser, 2014: 32), precisely in an increasingly educated society that exhibits a growing interest in collaborating.

In particular, citizen science takes on special interest in the phenomenon of public controversies on science and technology issues, defined as those scientific and technical controversies that go beyond the boundaries of the scientific community and reach public forums such as parliaments, the media or the courts. It should be noted that this type of controversy occurs regularly in the public sphere, initially triggered in the 1960s by a process of delegitimization that science experienced as the public became aware of the dangers of the atomic age and the influence of intellectual currents such as environmentalism. Increasingly, initiatives have thus emerged from local communities outside academic settings in response to specific problems of their interest —and which may or may not even involve scientists— (Kullenberg, 2015; Ottinger, 2010), often related to environmental issues (Brulle & Pellow, 2006). A pertinent and more general observation regarding participatory engagement is that "some scientists are made anxious by that change and worry about losing control of their research or being exposed to unpredictable interactions with the public", since scientists are "used to representing the authority of science unilaterally in their interactions with the public" (Kaiser, 2014: 27).

In sum, while collaborations between the scientific community and the public can provide a larger scale understanding of certain processes and thus contribute to scientific progress, as noted above, they can also provide a way for politicians, scientists and the people involved to connect.

3.1. The term (polysemy and hybridisation)

The term "citizen science" emerged in the mid 1990s (Cohn, 2008). It was coined independently, on the one hand by sociologist Alan Irwin, to refer to citizen participation in science deliberations, and on the other hand by ornithologist Rick Bonney, to refer to public participation in science projects (Bonney et al., 2009; Strasser et al. 2019). Since then, there have been several attempts to provide definitions of citizen science along both of these lines[10]. Generally, academic discourses on the two approaches have developed separately.

> When natural scientists use the term public participation, they usually refer to collection of data with the assistance of volunteers, whereas social scientists instead refer to representative engagement of stakeholders in policy processes. These double meanings are sometimes conflated on a policy level and attached with high expectations for the future of CS [citizen science]. (Kullenberg & Kasperowski, 2016: 10).

However, given the increasingly obvious overlap between both approaches, theoretical proposals have been offered that encompass both visions of participation through dialogue and co-research. Thus, deeper reflections on the conception of citizen science have given space to hybrid proposals -some examples can be found in Shanley et al. (2019) or in Heigl et al. (2019).

A comprehensive review of the term that takes into account theoretical, historical, geopolitical, and disciplinary aspects can be found in Eitzel et al. (2017)[11], including a wide spectrum of nuances employed by different scholars. It seems impossible to construct a definition to encompass all citizen science practices (Auerbach et al., 2019). In addition, it has been noted that "The various typologies for citizen science differ in their normative perspectives on the role and function of citizen science and the terminology they use" (Schrögel & Kolleck, 2019: 5), and there is no single theoretical framework that encompasses these normative, epistemological and structural differences of citizen science projects (Schrögel & Kolleck, 2019).

As a result of a scientometric analysis of more than 2500 articles, Kullenberg & Kasperowski (2016) found that the term is barely found from articles published in the mid-1990s and its presence grows gradually until around 2010, when there is a significant increase in the literature linked to the emergence of pharaonic projects such as Galaxy Zoo (). In their analysis, the authors distinguish between two approaches, on the one hand, that of the natural sciences, related to scientific production and the method that provides the possibility of mass analysis of large data sets (participation in observations, data collection, classifications...); while another approach from the social sciences pays attention to the idea of democratizing science in society and the influence on political decision-making processes, such as citizen participation in environmental problems. In fact, they found that the notion of "public engagement" was closely related to the term.

Another study with repositories of papers, noted that the term citizen science does not encompass the full scope of projects involving citizen volunteers, as for many projects scientific production is not a primary goal and they do not use the term as such (Follett & Strezov, 2015). Indeed, Kullenberg & Kasperowski (2016) also pointed out that the social actions[12] involving intervention in policy making that are sometimes undertaken in citizen science practices, and which could be encompassed within the term, are hardly traceable through the literature.

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[10] A lucid attempt is that of Lewenstein (2004): «The terms "citizen science" and "citizen scientist" have at least three meanings: (1) the participation of nonscientists in the process of gathering data according to specific scientific protocols and in the process of using and interpreting that data; (2) the engagement of nonscientists in true decision-making about policy issues that have technical or scientific components; and (3) the engagement of research scientists in the democratic and policy process». (Lewenstein, 2004: 1).
Other definitions can be found, for example, here (open the "citizen science" drop-down menu): https://www.weobserve.eu/cops-glossary/; and here: https://github.com/lshanley/CitSciDefinitions (CitiSciDefinitions, 2019).

[11] The authors warn that terminology is relevant when constructing knowledge. «People draw boundaries using language, choosing terms that include or exclude ideas, activities, and people (Gieryn, 1999)».

[12] For their part, Kasperowski & Brounéus (2016), in addition to distinguishing between citizen science as a method of knowledge production and as a participatory mechanism to socially legitimize science in the political arena, also propose a third meaning as "citizen mobilization, with the aim of exerting legal or political influence on certain issues".

Among its various meanings, providing different nuances —sometimes fuzzy— one speaks of *participatory science*, *community science*, *public science*; *crowdsourcing*; *participatory action research*; *community-based research*; *public participation in science and research*; public participation in scientific projects (Heigl et al., 2019), *civic science* (Kruger & Shannon, 2000); *do it yourself science* (Nascimento, Pereira & Ghezzi, 2014), *street science* (Corburn, 2005), *crowd science* (Franzoni & Sauermann, 2013)... and so on[13]. Some of these terms, such as "participatory science", are often used as synonyms for citizen science (Shirk et al., 2012). Additionally, it is worth mentioning that some authors try not to use the term "citizen science", as they consider it to exclude communities or individuals that do not have the legal status of "citizen", such as political refugees.

Finally, it remains to emphasize the aforementioned change in the conception of citizen science at the European level[14], which is reflected in the framework of the strategy *Horizon 2020* [15] *- Science with and for Society*, where we find the association of the term "citizen science" to the co-production of knowledge.

> There is increasing interest, and occasional experiments in processes of co-construction (e.g. agenda-building and policy inputs, co-evaluation, co-funding) and co-production (e.g. citizen science). (...) While traditional approaches to public engagement will remain, this topic constitutes an opening towards the 'new wave' of public engagement where 'co-creation' is a key notion. (European Commission, 2016: 16).

The two conceptual strands will be examined closely below.

3.2. Citizen science as a form of public engagement

As has been pointed out, a broad notion of the engagement strategy (see 2.2.ii) would include a multitude of activities, from those promoted by institutions —such as surveys and general campaigns, meetings with "mini-audiences", consensus conferences, citizen juries, extended peer reviews or deliberative mapping; these being the most studied in academia for their declared purpose of democratizing science—, to more informal ones —such as events on university campuses, talks with question time, demonstrations that include audience participation, science cafés, science in the bar, etc—. Spontaneous activities such as civil society associations to defend interests or points of view —for instance, in medicine, those led by patients are frequent—, and projects that are expressly defined as citizen science would also form part of this commitment.

Paying attention to the flow of information between the publics and the sponsor, the following participation mechanisms have been proposed (Rowe and Frewer, 2000; 2005): (i) public communication: information flows unidirectionally from the initiative's promoters to the public —including mechanisms such as information broadcasts and static website resources—; (ii) public consultation: information is also unidirectional but flows in the reverse direction from the public to the promoters of the initiative —including opinion polls, referendums, focus groups or interactive websites, etc—; and (iii) public participation: information is exchanged through a two-way dialogue between members of the public and promoters —mechanisms for public participation include

[13] Many of these terms refer to collaboration between local knowledge and academia.
[14] It can also be useful, for framing citizen science practices, the ten principles proposed by European Citizen Science Association (ECSA) (see Annex).
[15] «With the aim of deepening the relationship between science and society and reinforcing public confidence in science, Horizon 2020 should favour an informed engagement of citizens and civil society on research and innovation matters by promoting science education, by making scientific knowledge more accessible, by developing responsible research and innovation agendas that meet citizens' and civil society's concerns and expectations and by facilitating their participation in Horizon 2020 activities». Official EC for Horizon 2020".

action planning workshops, citizen juries, consensus conferences and working groups—[16]. The dialogic conception of citizen science would be framed in the third.

Bucchi & Neresini (2008), based on the previous work of Callon et al. (2002) on hybrid forums, develop their own typology in a two-axis diagram, where the vertical axis refers to the intensity with which citizens participate in the processes of building new knowledge, while the horizontal axis distinguishes "sponsored" activities from those that are spontaneous and instigated by the citizens themselves. Both dimensions are conceived as a continuous process in which there are different gradations.

	Low intensity	**High intensity**
Promotion	National debate Mediation Referendum Public Hearing Opinion Poll Focus Group Parliamentary Hearing Technology Assessment Office	Citizen panel Negotiated management Consensus conference Citizen's conference Citizen advisory committee Science and technology forum Constructive technology assessment Science and Technology Agendas Science Shop
Spontaneity	Public Protest Discussion forums	Litigation Extended Peer Community Hybrid forums Technology activism

Credit: García Rodríguez and Díaz García (2014: 11) based on Bucchi and Neresini (2008).

Another typology, perhaps more interesting, is the one developed under the project *Public Engagement Innovation for Horizon 2020* (PE2020), with five categories based on two parameters: the objective of the engagement mechanism and the direction of the information flow (Mejlgaard et al., 2015: link).

Type	Objetive	Information flow	Examples
Public communication	Informing and/or educating citizens	From sponsors to citizens (no feedback)	Public Comments Public hearings. Awareness-raising activities
Public activism	Influencing public authorities in decision making	From citizens to sponsors	Demonstrations Protests
Public consultation	Informing public opinion decision-makers on certain issues	From sponsors to citizens (without dialogue)	Citizen panels Planning for real groups Focus groups

[16] Although this proposal opens the way to impact evaluation (García Rodríguez & Díaz García, 2014), it has some drawbacks: it restricts public participation to a concept of information flow and is problematic because it does not capture spontaneous forms of participation and ignores its open nature, so that, its results do not always coincide with the initial objectives (Bucchi & Neresini, 2008).

Public deliberation	Facilitate group deliberation on policy issues and the outcome may have an impact on decision making.	Bidirectional communication; dialogue is facilitated	Mini-publics such as: - Consensus conferences - Citizens' juries - Deliberative opinion polls
Public participation	Assigning citizens full decision-making power in policy issues	Bidirectional communication; dialogue is facilitated	Joint government in direct democracy: - participatory budgeting - youth councils - binding referendums

Own elaboration based on Mejlgaard et al. (2015).

As a limitation, it has been noted that studies on participation tend to evaluate only its final phases and not the design process (Lengwiler, 2008), and it has been pointed out that thought should be given to how to achieve a more plural representation of the actors (Stirling, 2008). Other authors emphasize the distinction between participation and representation by pointing out that participatory processes suffer from hierarchical power relations, so that mere participation would not automatically result in a system of representation in which non-experts have the means to express their concerns (Jasanoff, 2003). For the interested reader, in an article analyzing 20 years of engagement, Stilgoe, Lock & Wilsdon (2014) warn of the need to develop new lines of argumentation and analysis by viewing engagement in a broader political context.

Finally, we can include in the discussion the other conception of citizen science.

In academia, public participation in science has been postulated as desirable in recent years and has advocated for a co-construction of scientific knowledge (Jasanoff, 2005; Bonney et al., 2009), co-design (Evans & Terrey, 2016) and legitimizing hybrid research practices (Callon, 1999; Callon, Lascoumes, & Barthe, 2002). The degree of participation would vary across disciplines, being more limited in some natural sciences and engineering where participation takes place at the end of the process, and broader in the medical and biomedical sciences, where participation is required for the development and design of therapeutic treatments (Kleinman, 2000). In this sense, a distinction has been proposed between "bottom-up" engagement at very early stages of the process of scientific and technological development, and "top-down" engagement after the decisions have been taken to put it into practice (Wilsdon & Willis, 2004).

3.3. Project-oriented citizen science

Citizen participation in scientific projects has been gaining popularity over the years. These practices have taken off since volunteered computing, developed in 1999 within the SETI@home project (Anderson et al., 2002) aimed at the search for extraterrestrial civilizations. Since then, numerous projects have been developed with this technology, for which it is only necessary to download and activate certain software on home computers —there are many examples involving volunteer computing, such as LHC@home; Rosetta@home; among others—.

There are, in addition to this, other forms of participation that involve an active cognitive contribution (Grey, 2009). A paradigmatic example of this is the Galaxy Zoo project (Lintott, 2019; Madison, 2014), the first of the international platform Zooniverse of the Citizen Science Aliance[17],

[17] https://www.citizensciencealliance.org/philosophy.html

in which 150,000 citizens were involved during its first year. After a short training period in which images of galaxies are shown, volunteers are faced with information that has not been analyzed and which they must classify by differentiating between galaxy types according to their morphology. A task that would otherwise have taken 10 years was accomplished in 6 months (Woodcock et al., 2017). Naturally, today this type of project has been applied to other fields. Examples of this on the same platform are the classification of penguin populations through images —which currently has more than 650 thousand classifications made by about 42 thousand volunteers[18]— (Penguin Watch, 2021) or even the transcription of British soldiers' diaries during the First World War (Operation War Diary, 2014), a project promoted in collaboration with the Imperial War Museums and the National Archives of the United Kingdom. This type of contributions provides great inputs to different disciplines thanks to mass observation[19].

In addition to the fact that the topics of the projects are very diverse, it can be emphasized that they are launched from different parts of the world within government-driven programs. Thus we find examples ranging from the collection of geo-referenced biodiversity data —for example, through bird counts for one of the most popular citizen science projects, eBird, led by the Cornell Lab of Ornithology with the support of the US government (eBird,)[20] and which has provided more than 100 million bird records to date—, to contributions of a different nature such as the detection of potentially dangerous asteroids for the Earth, a project conducted by the Spanish Virtual Observatory (SVO)[21]. The latter is one of the projects in the European repository *EU-Citizen.Science*, a platform designed within the European Union's *Horizon 2020 Framework Programme for Research and Innovation* for the exchange of citizen science projects, resources, training and tools, which currently has 186 ongoing projects, 142 resources —educational, policy-oriented, among other approaches—, 26 training tools and 142 organizations involved (EU-Citizen.Science, 2021). These examples illustrate both the interest of public authorities in citizen science and the richness and diversity of the field.

In this way, citizen science makes it possible to collect a quantity of data that would otherwise be impossible, in addition to the fact that: "Citizen Science does not only generate data; in many projects immense value is added by annotation and more advanced forms of analysis done by citizens" (Masó & Wehn, 2020: 2). For these reasons, some scientists have seen the opportunity to obtain free labor and benefit from the computing power and cognitive skills of a public interested in science (Cohn, 2008; Silvertown, 2009).

While there are plenty of web-based services and resources on citizen science, a more recent way of getting involved in science is also the growing use of cell phones to record data, for example to measure environmental noise levels (Maisonneuve et al. 2010) or air quality (Cuff et al. 2007).

[18] By way of illustration, read the following comment from a project collaborator: «I really hope I'm not the only one. I really enjoy helping out, I love seeing all the Penguins and beautiful landscape. I have done 59 classifications and It's taken about 4 hours. I zoom in and out adjust lighting even use a Magnifying glass to ensure my classification is correct. Am I doing too much ? By the general rule of 70 an hour I'm really off. Just wondering, I have plenty of time to dedicate to this project and plan on doing so» (Zooniverse, 2021: link).

[19] Note that pattern detection in images through computational techniques has until recently lagged behind the possibilities provided by human cognition, as in the case of galaxy categorization (Lintott, et al., 2008). While new applications in artificial intelligence, specifically in the field of deep learning, have been shown to be faster and more accurate in data processing, note that citizen scientists play a key role in training the algorithms —for example, it has been shown for counting wildlife in aerial survey images— (Torney et al., 2019).

[20] https://www.citizenscience.gov/ebird-bird-data/

[21] «Apophis is an excellent example of how important Precovery can be. Discovered on June 19, 2004, follow-up observations indicated a small probability (up to 2.7%) that it would strike Earth in 2029. It was not until precovery images taken in March 2004 were analyzed when the possibility of an impact on Earth was eliminated» (SVO: link).

Also worth mentioning is the so-called maker movement, which refers to citizens who use science to build their own devices, for example using arduino, and even more controversial practices such as *biohacking*.

In short, an individual may participate in a given project in different ways —data collection, interpretation and information delivery— and with different levels of involvement.

> […] from citizens donating the processing power of their personal computers to perform scientific calculations (SETI@home), to amateur naturalists collecting observational data outdoors about birds (eBird), city residents mapping air pollution (City Sense), people classifying online images of galaxies from home (Galaxy Zoo), patients sharing quantified observations, symptoms, and experiences about their health (PatientsLikeMe), and biohackers attempting to produce insulin in a community laboratory (Counter Culture Labs). (Strasser, 2019: 1-2).

Regarding the type of audiences, paying attention to institution-driven projects, it has been highlighted that citizen science projects «tends to appeal to a narrow type of audience, namely, those already attentive to and supportive of science» (Martin, 2017:). In the debate on inclusion, there is a predominance of positions that advocate designing more inclusive projects that appeal to other groups that are being left out. The following reflection on audiences likely to participate is interesting[22]:

> […] with the increase in the demands of secondary education, many who have dropped out of school even are equipped with basic scientific knowledge that is sufficient to make them effective participants in citizen science projects. For many of these people, education provided a starting point for an interest in science, which is not fulfilled in their daily activities. Thus, citizen science provides an opportunity to explore this dormant interest. (Haklay, 2013).

It is worth mentioning, following this line of reasoning, that participation in citizen science projects also faces some obstacles. Among the most relevant is the fact that they may be difficult to understand for the average citizen —language, tasks to be performed, etc—[23] and that the benefits that individuals obtain from their participation may not be evident. Debate has also been generated around the use and generation of data (Scassa & Chung, 2015), mainly in view of the claim that participants deserve privacy and recognition for their work (Masó & Wehn, 2020). Thus, with respect to intellectual property it is pertinent to ask who owns the results (Woodcock et al., 2017). Related to this, it has been pointed out that scientists themselves must rely on the capabilities of the public and, ultimately, on the data generated through citizen participation (Woodcock et al., 2017).

Likewise, tensions may arise around the understanding and application of citizen science when users' motivations and expectations conflict with the design and implementation of projects —ideas about data visibility; hierarchies among citizen-scientists; communication of objectives…— Verploegen et al. (2021). Since citizen science is perceived differently by the agents involved, both transparency and consistency in communication are desirable aspects in projects. From the European Framework, it has been emphasized that a «claim by some experts in the community is that Citizen Science platforms and software should be free to use and preferably

[22] Others, however, argue that: «Citizen science is touted as a means of making science more inclusive and democratic. However, when citizens are drawn from societies with significant socioeconomic and racial disparities, citizen science may reproduce the same structural oppressions that exist in society at large» (Ott & Knopf, 2019).
[23] It has been proposed that citizen science projects must be: "From user perspective: user-friendly, wide accessibility and easy to navigate through" (WeObserve, 2021).

open source, as this would best fit the initial idea of voluntariness, openness and collaboration» (Socientize Consortium, 2013: 30).

In addition, another concern has been that the resources to implement a given project may not scale with respect to the potentially relevant data (Masó & Wehn, 2020). Also, since projects can operate either locally or on a large scale, a pertinent question here is: do those with a local scope also respond to global objectives? If the objectives go beyond mere scientific advancement —for example, informal education and engagement— this question would not pose a problem.

3.4. Degrees of participation

From academia, theoretical models have been proposed that account for both the way in which participants are integrated into citizen science projects and their degree of involvement. Regarding the degree of participation, essentially three basic models can be traced that show an increasing involvement of the public. The distinction starts from the so-called ladder of participation of Bonney et al. (2009), which appears hierarchical towards a more egalitarian approach to the production of scientific knowledge (Haklay, 2013). Drawing on different authors who address this distinction —Haklay (2013); Wiggins & Crowston (2011); Bonney et al. (2009); Cooper et al. (2007); Wilderman (2007)— the following is a description of three levels of participation and engagement in citizen science projects that exhibit increasing inclusion of the lay public:

- **Contributory**: in projects designed by experts, participants provide resources —as in distributed computing— or participate in data collection —for instance, through crowdsourcing programs for data collection via mobile devices or exchanges in social media that can be found in so-called Citizen Observatories (COs).
- **Collaborative**: in projects generally designed by scientists, participants can get involved by contributing to the analysis of data and discussing the interpretation of results, as well as collaborating in the dissemination of research. It is the scenario for the co-construction of knowledge.
- **Co-created**: participants are involved in all stages of the scientific process. They can propose and decide research topics, formulate the research questions, design methods, etc. Research questions can be established through deliberative processes (Schrögel & Kolleck 2019).

Regarding the last level of participation, it is worth mentioning an extension of it that has been called "extreme citizen science" (Haklay, 2013), for which volunteers work with scientists as equals and have the status of co-researchers, being present in the publication of results[24]. In these cases it is often the communities that express their needs for action (Cunha, 2015). An example may be the 2010 BP spill, near the Louisiana coast, since «volunteers started to document the extent of environmental damage and researchers were involved in the collaborative development of portable measurement instruments for citizens» (Schäfer & Kieslinger, 2016: 4).

For their part, Shirk et al. (2012) complete the three modes of participation with two others: *contractual projects*, for which communities demand certain research on issues that affect them

[24] In the EU-funded project *Extreme Citizen Science: Analysis and Visualisation (ECSAnVis)*, led by Haklay, it is stated that «The challenge of Extreme Citizen Science is to enable any community, regardless of literacy or education, to initiate, run, and use the result of a local citizen science activity, so they can be empowered to address and solve issues that concern them» (ECSAnVis, 2016-2021: https://cordis.europa.eu/project/id/694767/es).

and that normally influence local policies —and even scientists can ask citizens to carry out research and report results—; and *collegial contributions*, where the aforementioned maker movement and the hacker community are framed, whose members operate autonomously and independently without the supervision of professional scientists.

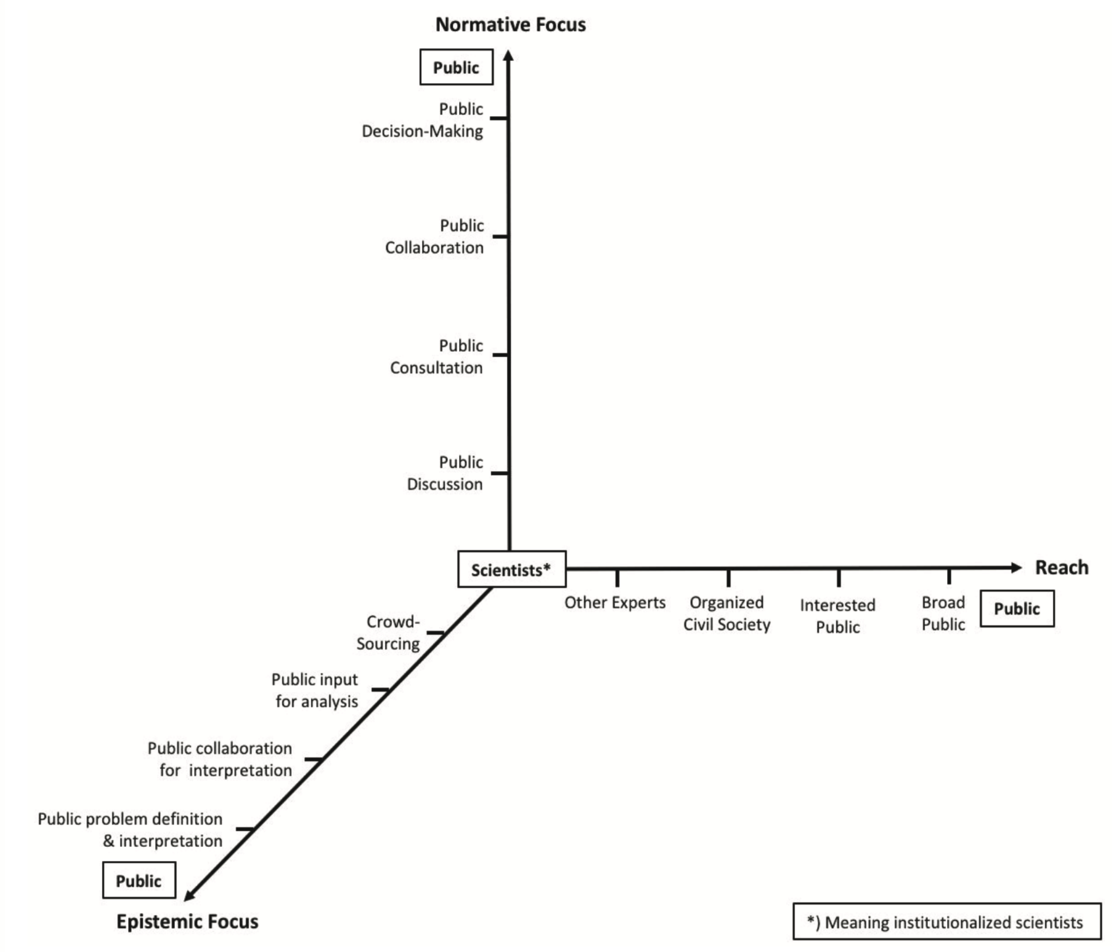
On the other hand, different typologies have also been proposed to categorize the manner in which individuals participate in projects. There are classifications that consider the practical aspects of execution and implementation, such as whether the project drivers are scientists or citizens, the local or global scale, the objectives of the project —pattern detection; hypothesis testing…— (Dickinson & Bonney, 2012: 6), and even the dissemination of project-derived products such as algorithms or data (Franzoni & Sauermann, 2013). By way of example, a possible classification, paying attention to when participation takes place and according to the classic stages of the scientific process —defining the problem, setting the agenda, collecting data, analyzing, interpreting, disseminating— is that of Wilderman (2007), who proposes three types: *community consulting model* —here science shops would come in—; *community workers model* —data and analysis—; *community-based participatory research model* —including projects in which all tasks are led by citizens (Whyte et al., 1991)—.

Another approach to categorization is to look at structural aspects, such as agenda setting or information management, which, as noted above, includes decisions about the intellectual property of the results, as well as other aspects related to the requirements and resources needed from participants, project evaluation criteria, among others[25]. (Prainsack, 2014). Woolley et. al (2016) distinguish between *participation*: active/intentional or passive, *engagement*: to the extent that scientists ask for help, and *involvement*: active role in the planning and execution of the project[26]. Undoubtedly, the possibilities for categorizing participation are overwhelming: there are almost as many as there are authors.

In any case, perhaps notable here is Schrögel & Kolleck's (2018) three-dimensional descriptive framework, which attempts to encompass normative, epistemological, and structural differences. This framework addresses both dialogical formats and co-research, through what they call the "participatory science cube" —based on the idea of democracy cube (Fung, 2006) applied to participation and dialogue in science— and would be broad enough to include all forms of participatory approaches with attention to who participates, how, and who decides. They thus define three axes: one normative, one epistemic and one related to scope (See Figure).

[25] For example, Wiggins & Crowston (2011) proposed five types of projects empirically classified by paying attention to common characteristics among a sample of projects: Action, Conservation, Investigation, Virtual, and Education. They further identified two major clusters with respect to stated objectives and the tasks to be performed, which could be virtual or face-to-face (Wiggins & Crowston, 2012).

[26] In the Woolley et al. (2016) classification, "public deliberation" is not considered part of "participation".



(Schrögel y Kolleck, 2019: 12)

Finally, one aspect of the debate that deserves special attention is the claim of some authors to the question of the quality of the participation process, such as Shirk et al. (2012). In addition to distinguishing the degree of participation in projects, these authors classify them according to the quality of public participation during project design: "the extent to which a project's goals and activities align with, respond to, and are relevant to the needs and interests of public participants" (Shirk et al., 2012: 29). There must be a —negotiated— balance between public and scientific interests. According to the authors, the key components of high-quality participation are:

- "credibility and trust (Wynne 1992, Wulfhorst et al. 2008),
- fairness (Rowe and Frewer 2005, Cheng et al. 2008),
- responsiveness (Gaventa 2004),
- relevance (Cumming et al. 2008),
- agency (Cleaver 2004),

- and due diligence in the development of appropriate research strategies (Cheng et al. 2008)".

Shirk et al. (2012: 28-29)

3.5. Motivation

From the collective point of view, motivation for citizen science can be defined in terms of the social and scientific values and benefits it brings; while from the individual point of view, the individual motivations that favor participation in projects can be examined. In a participatory culture, members feel connected to the rest of the participants and consider their contribution relevant (Jenkins et al. 2009).

(i) Value of citizen science

In addition to benefits for research, citizen science also brings social and political benefits (EU-Citizen.Science, 2021). Indeed, the potential of citizen science lies in the potential innovations in the scientific, social and political domains (Turrini et al., 2018). Essentially, the current promises of participation and citizen science are: democratization, education, and discovery (Strasser, 2019). Let us look at all three below.

First, the idea of democratization in the production of knowledge (Irwin, 1995) has been widely explored in the literature, as an opportunity for citizens to enjoy science, to contribute to scientific progress and even to know where part of their taxes go. Thus, citizen science would serve, on the one hand, to spread awareness of the scientific process (Trautmann et al. 2012), and on the other, to participate in it: "Promote democratic governance of science via public engagement and debate between policy makers, researchers, innovators and the general public in a structured channel for feedback and open criticism" (Socientize Consortium, 2013: 37).

In addition, the empowerment of the public is alluded to in the sense that a redistribution of power takes place between experts and laypeople through the "co-construction" (Callon) or "co-production" of norms (Jasanoff)[27]. An example to illustrate this is the study by Brouwer (2018), focusing on the future and value of citizen science in drinking water[28].

Also related to democratization, it should be noted that inclusion is a central term in citizen science[29]. On the one hand, it has been urged to design projects that not only consist of data collection but also involve people so that they feel part of the science club, and on the other hand, it has been invited to reflect on how values fit together to create projects that have more benefit and meaning in certain communities (Purcell, Garibay & Dickinson, 2012). In this sense, for example, the ExCiteS project (2011-2016) combined local environmental knowledge with scientific analysis to improve environmental management, and showed how scientifically illiterate people in Congo and can successfully participate not only in data collection but also in formulating research questions (ExCiteS, link). Citizen science, indeed, contributes to the broader goal of building an

[27] The European Commission employed the slogan "Towards a better society of empowered citizens and enhanced research" (Socientize Consortium, 2013: 1)

[28] In this regard, some point out that such civic empowerment would be fostered by the recognition of citizen science held by public authorities (Turriti, 2018).

[29] By its very idiosyncrasy, citizen science brings together very diverse people: «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. 2019)». (Llorente et al., 2021).

inclusive society (Schäfer & Kieslinger, 2016), and moreover: it requires inclusion by definition (Golumbic et al., 2017)[30].

Second, it has also been argued on several occasions that citizen science can be an effective tool to increase scientific literacy (Bonney et al. 2016; Jordan et al., 2011) through education and outreach (Heigl et al., 2019). In this regard, citizen science is said to have great potential to increase interest in science (Bonney et al. 2016; Flagg 2016) and to enhance learning (Ruiz-Mallén, 2016). Specifically, the practices of science communication in the framework of the projects have been explored and an attempt has been made to measure the knowledge or "learning outputs" of the participants (see section 4).

Third, citizen science also proposes an innovative research methodology that allows addressing otherwise intractable questions (Silvertown et al. 2011), by gathering massive data or interpreting results collectively (Delfanti, 2016). For example, from a natural science point of view, citizen science projects are valuable for their strategic capabilities with respect to issues such as time management (Dickinson, Zuckerberg & Bonter, 2010) and space (Bonney et al., 2009), as well as of costs and investment in large-scale observations, which are minimized (Bonney et al., 2009; Silvertown, 2009) while observational capabilities are expanded, being possible to perform classifications using large datasets (Sullivan et al., 2009) as is the case in the aforementioned Ebird or Galaxy Zoo projects. Here the valuable contributions of citizen science to sustainable development goals (SDG) can be highlighted (Fritz et al., 2019; Fraisl et al., 2020). It has been particularly successful in advancing environmental goals by facilitating civic engagement and learning, as well as raising climate awareness (Turriti, 2018).

In particular, note that governmental supports provided to citizen science consisting not only in providing economic resources but also in active involvement in the design and implementation of projects, have been shown to be key in the success of environmental policies (Bio Innovation Service, 2018). Furthermore, it has also been highlighted that citizen science has the potential to contribute to policy in a cost-effective way (Bio Innovation Service, 2018).

On the other hand, in light of the potential benefits of citizen science, Heigl et al. (2019) seek to ensure that participation is of high quality, both from the scientific point of view and from the interests of citizens, and for this purpose they propose different criteria to be evaluated in the projects: scientific criteria —“the scientific questions asked or hypothesis tested; the methods applied; and the rationale for generating new knowledge or developing new methods" (Heigl et al., 2019: 8091)—, and other criteria related to ethics, open science, collaboration[31]. The definition of these criteria would allow the community (networks, funding agencies, policy makers, platforms, associations...) and the rest of the participants, scientists and policy makers, to assess the quality of the projects, while the fulfillment of these criteria would act as a quality filter.

(ii) Individual motivation

The motivation of individuals to participate in citizen science projects is a complex interweaving of the intellectual, the civic and the emotional (Kaiser, 2014:27). Although the psychological factors underlying motivation are complex, it is useful to try to understand the mechanisms that activate it and for this purpose to take advantage of the possibilities for analysis

[30] Interestingly, it has been suggested that small research teams that include deliberation with citizens obtain better epistemic results, and in particular taking advantage of such diversity may be a way to bring epistemic quality in some social science settings with reduced cognitive diversity (De Brasi, 2020).
[31] As a curiosity, in this proposal the authors exclude those projects in which citizens contribute data with their smartphone on the grounds that the participants do not actively participate, they only provide resources such as computing power.

offered by the emergence of citizen science projects. In particular, motivation is important for informal learning (National Research Council, 2009), and indeed attempts have commonly been made to correlate motivation and learning outcomes (Dem et al., 2018). Understanding the motivation of individuals, can be useful, for example, for drivers to find effective ways to recruit participants and to retain them over time (Lotfian et al., 2020)[32].

In particular, it has pointed out that participation in citizen science is similar to that of other volunteer activities (Reed et al., 2013). In principle, general interest in science is not the *leitmotiv* for joining a citizen science project (Crall et al., 2012), but prior interest in specific scientific topics has been shown to be (Cosquer et al. 2012)[33]. In addition to interest, motivation may also be related to other factors, such as recognition (Rotman et al., 2012). On the aforementioned Zooniverse platform (see section 3.3.), it has been shown that many participate purely for entertainment (Woodcock et al., 2017)[34].

In principle, case studies are useful for gathering insights about motivation, however, it should not be ignored that it has not been uniformly defined or studied across the citizen science field (Phillips et al., 2018). Nevertheless, findings from anecdotal studies invite reflection and better experimental designs. Among the attempts to characterize the motivation of participants using particular citizen science experiences, one can highlight, in the field of astronomy, studies tasked to understand the motivations of volunteers, such as the aforementioned Zooniverse (Raddick et al., 2008) or more recently that of Bakerman et al. (2019). In biology, one can cite the study of the motivations of birdwatchers in South Africa (Wright et al., 2015).

Naturally, participants' motivations may vary, not only between individuals but also depending on the projects (Cox et al., 2018; Tiago et al., 2017) —thematic, objectives, accessibility…—.

> Motivational drivers and barriers for both scientists and volunteers are diverse and depend on the project type but also on the context in which volunteer engagement is taking place. While in some contexts providing valuable contributions to science or to the local community might be the most important motivational driver for citizens' involvement, in other contexts it might be monetary incentives, as only financial aid would render the participation possible for some participants. Intrinsic motivators, like the interest in the scientific topic or the satisfaction from contributing to science, have been identified as being amongst the most important drivers for volunteers' participation. (Socientize Consortium, 2013: 27).

Remarkably, a questionnaire study found no statistical differences in motivation between gender, age and education levels, although it did present different results for respondents with different levels of participation (Tiago, 2017).

Some studies suggest that there is an association between participants' motivation and the type of contribution they make to projects (Lotfian et al., 2020). Broadly speaking, several authors refer to *intrinsic* and *extrinsic* motivators (Eveleigh 2014), with the general recommendation being to encourage intrinsic motivations —such as positive feedback and adapted modes of participation (Tiago, 2017). By way of example, the framework for classifying volunteer motivation in citizen science projects by Lotfian et al. (2020), who propose (i) extrinsic attributes: including elements such as "altruism" —help scientists—; "enjoyment", "fulfilment" —gain new knowledge—; and (ii)

[32] Moreover, motivation can evolve over time (Tinati et al., 2017), which adds complexity to this endeavour.
[33] It can also be added that this initial interest may be virtually unchanged with participation, making it difficult to detect changes during an individual's participation in a project (Brossard et al. 2005; Thompson and Bonney 2007).
[34] For some, para que se produzca engagement "people without a professional or educational need to connect with science are likely to connect with it only if doing so is enjoyable" (Kaiser, 2014:38).

intrinsic: community —being part of a team or meeting new people—; ego enhancement —self-esteem and reputation—; and future return —rewards; monetary, certificates…—.

Note that some case studies have shown that volunteers who participate more frequently in citizen science tasks are more intrinsically motivated than those who participate less frequently (Bakerman et al., 2019). In this regard, it can be added that a previous study with three online citizen science projects found that motivation influences the quantity of participation, but not the quality (Nov et al., 2014). Related to this, it remains to comment that in the face of the failure of several citizen science projects due to low participation, the effects of using reward mechanisms to positively influence the participation and motivations of individuals have also been investigated (Cappa et al., 2018).

4. DELIBERATION

In academia, political reflections on participation emphasize the roles of the actors involved in deliberative processes, particularly on the degree of control and power achieved by citizens. In this sense, Sherry Arnstein proposed a ladder of citizen participation (Arnstein, 1969) that has served to differentiate between "good and bad forms of public participation" and has inspired later authors. For his part, Chilvers (2008) traces in the specialized literature —closely with Rowe & Frewer (2000; 2005) and others— a series of criteria for the exercise of participation to be effective:

- be representative of all those interested and affected by a decision or action and remove unnecessary barriers to participation (representativeness and inclusivity);
- allow all those involved to enter the discourse and put forward their views in interactive deliberation that develops mutual understanding between participants (fair deliberation);
- provide sufficient resources (information, expertise, time) for effective participation (access to resources);
- be transparent to all those inside and outside of the process about objectives, boundaries, and how participation relates to decision making (transparency and accountability);
- enhance social learning of all those involved, including participants, specialists, decision makers, and wider institutions (learning);
- be conducted (managed and facilitated) in an independent and unbiased way (independence); and
- be cost-effective and timely (efficiency).

(Chilvers, 2008: 159)

In the context of this discussion, the following comparison of representative and direct democracy models may also be of interest (Biegelbauer and Hansen, 2011: 591):

Table 1. Comparison of representative and direct democracy models

	Representative democracy	Direct democracy
Role of citizens	Elect politicians Support organisations to represent their interests	Articulate and develop own interests Participate in all stages of political process
Role of civil service	Effective and efficient professionals	Facilitators of collective decision-making, co-learners
Role of experts/ scientists	Producers of value-free knowledge offer cognitive support to particular causes	Support (self-) enlightenment of citizens by acting as co-learners
Role of politicians	Steers providing authority	Overseers meeting demands
Prime legitimation	Indirect: politicians are elected by citizens	Direct: through citizen participation at different stages of political process

In the field of science governance, there is a large body of academic literature that addresses various issues related to the participatory approach.

> Following the 'deliberative turn' in democratic theory and practice (Goodin, 2008), communication and dialogue became increasingly important for science governance and scientific policy advice. This led to the implementation of participatory practices for technology assessment, public dialogues on science and technology issues –especially on environmental aspects of these– and the development of various participatory methods from town-hall meetings to consensus conferences or citizen juries (Joss and Durant, 1995; Durant, 1999; Kasemir et al., 2003; Lengwiler, 2008). (Schrögel & Kolleck, 2018: 2).

Generally speaking, it is stated that "To be effective, citizen engagement has to be inclusive, deliberative and influential" (Schönwälder, 2021: 483). In this sense, deliberative democratic exercises should involve citizens and experts, benefiting all stakeholders.

> […] Scientific experts, stakeholders, and policy makers play supportive roles, providing data and education to inform the deliberation. (…) Public deliberation allows citizens to assess data

> and make recommendations that can be considered alongside those offered by scientists and policymakers. (Ott & Knopf, 2019).

In fact, for some scholars deliberative participation would be more important than direct contribution to knowledge production since it is precisely debate and deliberation that will bring about a socially robust science (Fiorino, 1990). "Processes used have drawn on techniques from political science: citizens juries (Wakeford, 2002) and councils (Davies, Wetherall, & Barnett, 2006), consensus conferences (Joss & Durant, 1995), or scenario workshops (Andersen & Birgit, 1999)" (Davies et al., 2012). For example, in situations such as the COVID19 pandemic, improving the interaction between citizens, experts and politicians through deliberative and citizen science would help to develop and legitimize government strategy (Pearse, 2020).

In particular, its importance in strengthening democracy is noted with the civic contribution to debates on controversies (Callon et al. 2009), a debate that, ideally, should be well-informed. Some have cautioned, however, that public deliberation need not necessarily achieve consensus, being "a challenge that requires citizens to identify, clarify, and weigh the tensions among their views and the values underlying them; justify them to others; and set priorities" (Blacksher et al. 2012: 15)[35].

Authors such as Mejlgaard & Stares (2013) or (Powell et al., 2011), draw attention to certain weaknesses of deliberation in science such as the fact that the random selection of citizens in sponsored participation is not so much as it is a subset of the public composed of people more attentive to science and technology issues and who "tend to be comparatively more alert and aware, with higher incomes, more liberal orientation, and comparatively better educational background than the average citizen (Powell et al., 2011)".

Others such as, Felt & Wynne (2007) criticize "that institutions focused on deliberation only after the innovation occurred, as if the public was only interested in the later issues." (Felt & Wynne, 2007) and advocate for "bottom-up" public deliberation. One form of bottom-up democracy could be, for example, the Shin-Gori Nuclear Reactor Public Deliberation Committee, established in 2017 in order to deliberate and decide whether to build a nuclear power plant in the area.

Another interesting point is that, although deliberation has so far been associated with political environments, the fact is that public participation within a deliberative framework is possible in other spaces. In this sense, Davies et al. (2009) point out that there are events that involve dialogue but are not intended to inform public policy, and that these are little studied - and are generally explained by appealing to the deficit model, although there are other ways of framing them. A research by Davies et al. (2012) analyzed, precisely, three case studies with deliberative processes involving change in urban planning and development. The so-called "science shops" stand out here, and their purpose is precisely to gather the interests and demands of citizens in relation to science. They are mediating spaces between scientists and citizens to respond to the knowledge needs of the population and to propose research directions -some examples, mostly in Europe, can be found here: link. As regards citizen influence on research directions, cases can be cited such as a research on AIDS in which a brainstorming session was held Spain in by Andalucía MejorConsciencia Fundación Descubre (). Some other examples can be found in Hemmet et al. (2011).

[35] Ideally, deliberation implies consensus (Cohen, 1989).

As we have seen, the question of deliberation in citizen participation in science has generally revolved around the type of participation (Irwin 2001; Wynne 2006) since in the dialogic conception of citizen science, the public is an active agent in debates and deliberations about science and technology (Irwin & Wynne, 1996).

Increasingly, however, citizen science projects are not approached as a deliberative process but are associated with knowledge production (Macq et al., 2020). Regarding this co-construction of knowledge, it has been suggested that citizens should be involved in all stages towards decision making; and for this, scientists should assist and act as co-learners, while citizens should self-enlighten and develop their interests (Biegelbauer and Hansen, 2011). It has also been reproached that, despite the supposed third wave of democratization —see 2.1.—, individuals are often not ultimately involved in the technical decision-making process —for some, technical issues should theoretically be open to all (Chiou, 2019).

In this sense, the change of focus in the policies of the European Union is very illustrative. In Europe, in the 2000s, deliberative processes were promoted —in fact, the institutionalization of public participation was originally deliberative (Greenwood et al. 2002)— and discussion forums were created for deliberation on science and technology issues (Grove-White et al., 2000)[36]. Since 2010, on the other hand, productive models of citizen science have prevailed. Note that, in the aforementioned *Green Paper on Citizen Science: Citizen Science for Europe* (2014), co-created projects are advocated and their results are claimed to serve well-informed decision making, however, the document does not invite citizens to deliberation with policy makers. This evolution in the European discourse around citizen participation in science has been analyzed by Macq et al. (2020)[37]. See below for a table that may be illustrative:

Table 1 Characteristics of the two discourses of the European Commission on public participation in science and technology

	Participation in decision-making	Participation in knowledge and innovation-making
What	Decision (policymaking)	Knowledge and/or innovation
Who	Society, public (collective)	Citizens, users, consumers (individuals)
How	Dialogue (discussing)	Co-creation (producing)
Why	Generate legitimacy (trust)	Produce economic and societal value (commodities)

(Macq et al., 2020: 507).

[36] Attention to deliberative participation in Europe crystallized with the publication *Science and Society Action Plan* (European Commission, 2002), which proposes actions such as dialogues, and is followed by programs such as *Science in Society* () or the document *Taking European knowledge society seriously* (Wynne et al., 2007).

[37] «The introductory paragraph of the 2018–2020 Science with and for Society Work Programme foregrounded citizen science: "[Science with and for Society] will explore and support citizen science in a broad sense, encouraging citizens and other stakeholders to participate in all stages of R&I" (EC 2017). The Work Programme mostly defined the expected outcomes of citizen science in terms of the "Development of new knowledge and innovations by citizen scientists" (p. 37), while downgrading "Agenda setting" and "foresight," two essential parts of the "deliberative" model of public participation, as optional criteria for the contribution to implementing RRI (in this case through its 'public engagement' dimension) (p. 8)». (Macq et al., 2020: 505).

In a survey of the lexicon used in defining the objectives of European participation programs, the authors distinguished between two groups: (i) one focused on deliberative public participation in policy-making —'democratic debate,' 'dialogue,' 'consultation,' 'deliberative process'—; and (ii) another focused on participation in research and innovation —"user innovation", "user-innovation", "participatory research", "participatory innovation", "citizen science", "co-creation"—. It is significant here that mentions of deliberative public participation in European Commission-funded projects increased to almost 40% after 2004, while they then dropped to less than 12% with *Horizon 2020 - Science with and for Society*, and already as of 2016 terms related to participation in research and innovation far exceed them (Macq et al., 2020). One reason they find possible to explain this change is the changing policies of the EU.

The above shows the relevance of opening a dialogue between approaches focused on the empirical side of research projects and those that emphasize the normative aspects of participatory processes. For Legrand & Chlous (2016) it would be a matter of "enhancing the transformative potential of participatory practices towards increasing epistemic plurality" (Legrand & Chlous, 2016:).

In any case, Lewenstein's question regarding CS seems very pertinent: «What kind of "citizenship" does citizen science produce, and what is the relationship of that citizenship with authority in policy debates and science-based decisions about management of [for example] natural resources?» (Lewenstein, 2016: 1).

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ANNEX: ECSA's Ten principles of citizen science

The European Citizen Science Association (ECSA), proposed the following principles to frame citizen science:

1. **Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding.**
   Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.

2. **Citizen science projects have a genuine science outcome.**
   For example, answering a research question or informing conservation action, management decisions or environmental policy.

3. **Both the professional scientists and the citizen scientists benefit from taking part.**
   Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g. to address local, national and international issues, and through that, the potential to influence policy.

4. **Citizen scientists may, if they wish, participate in multiple stages of the scientific process.**
   This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.

5. **Citizen scientists receive feedback from the project.**
   For example, how their data are being used and what the research, policy or societal outcomes are.

6. **Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for.**
   However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science.

7. **Citizen science project data and meta-data are made publicly available and where possible, results are published in an open access format.**
   Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this.

8. **Citizen scientists are acknowledged in project results and publications.**

9. **Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.**

10. **The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.**

September 2015, London

Source: https://ecsa.citizen-science.net/2016/05/17/10-principles-of-citizen-science/