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# Citizen science and participatory science communication: an empirically informed discussion connecting research and theory

**Paolo Giardullo, Federico Neresini, Esther Marín-González, Cristina Luís, Joana Magalhães and Rosa Arias**

**Abstract**

Citizen Science is believed to contribute significantly to the democratisation of science, engaging non-scientists in scientific research. Participatory approaches to science communication share the same interest through public participation and public engagement. In the attempt to connect these two debates both theoretically and empirically, we provide an analysis of the communication tools and strategies used by 157 Citizen Science projects across the EU, UK, and Switzerland. Our analysis reports that the CS projects surveyed tend to interpret communication as a disseminating activity, rather than as a tool to promote appropriate communication-based encounters with both project participants and other potential target audiences.

**Keywords**

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

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## Introduction

Participatory approaches to science communication are developed to promote public participation and public engagement, shifting the paradigm from public understanding of science to a more integrated framework. Indeed, the current trend among research-funding institutions is to encourage researchers to plan tools and strategies for communication campaigns: for example, coordinating dissemination efforts as well as assessing societal impact as part of the research project's life cycle [Mollett, Brumley, Gilson & Williams, 2017]. Citizen Science (CS) is believed to contribute significantly to the democratisation of science, engaging non-scientists in scientific research [Strasser, Baudry, Mahr, Sanchez & Tancoigne, 2019].

CS is gaining momentum as an enabler of outreach activities [Magalhães et al., 2022] in the general context of recent EU framework programs explicitly calling for

projects that should guarantee society's participation through dedicated engagement activities in order to be funded [Entradas et al., 2020]. This means that research projects should embody a pluralistic perspective that encourages reflexive and critically informed multi-stakeholder discussions. Engaging the public is widely recognised as a key asset to scientific research for the pursuit of the political legitimacy of innovation processes and scientific knowledge construction [Stilgoe, Lock & Wilsdon, 2014]. According to Alan Irwin [2008], integration between scientists, non-scientists, and public values is highly desirable for dealing with social complexity. This perspective has further grown within the Responsible Research and Innovation (RRI) framework, which considers mutual responsibility between societal actors and innovators as a key feature to achieve in contemporary society [Von Schomberg, 2013] in a path of the increasing democratisation of scientific research and technological innovation, moving from a government of scientific research for the common good to a proper governance of innovation [Borrás, 2012].

This is mentioned by many as the new maxim [Macnaghten, Kearnes & Wynne, 2005] that attempts to engage non-scientists in less canonical ways, rather than considering them as mere recipients of top-down messages [Jensen & Buckley, 2014], and it is further endorsed within the open science perspective. Within this approach, the openness of science would reside precisely in the opportunity for society to take part in the knowledge production process and to further promote paths for including citizens' contributions within the research processes [Macq, Tancoigne & Strasser, 2020]. The shared orientation towards dialogic approaches, as promoted by the literature in public engagement, however, is hard to be found in practice when we consider scientists' opinions about the public: they tend to reproduce deficit model and to interpret science communication consequently as top-down approach remaining endemic [Cook & Zurita, 2019; Simis, Madden, Cacciatore & Yeo, 2016]; expectations for adopting a participatory approach are thus far from being the dominant communication strategy nor an easy task to be performed as recent researches demonstrate [Nerghes, Mulder & Lee, 2022].

These expectations and calls to engage societal actors in conducting research can be met by Citizen Science (CS) projects. In fact, some research-funding institutions already list CS among the ways of fulfilling public engagement [European Commission, 2018, 2020]. Analytically, the potential outcomes of CS activities resemble many of the aims of science communication; Strasser et al. [2019] sums up them defining as the promises of CS for science and society relationship. Besides improving scientific literacy as well as producing knowledge that would not be possible otherwise, CS is believed to support effective citizen engagement [Golumbic, Orr, Baram-Tsabari & Fishbain, 2017; Oberbauer, Lai, Kinsey & Famula, 2021]. This means that the practice of CS goes far beyond the opportunity to carry out finer data collection, integrating itself into a framework of public participation in science [Skarlatidou & Haklay, 2021]. As pointed out recently [Wagenknecht et al., 2021] CS may open up the research process to external actors such as policy-makers, firms and industries, and civic society, thereby further fostering participatory communication processes and potentially fruitful encounters. Such a potential benefit from CS cannot be denied; however, several findings from the assessment paths do not entirely confirm the claims for benefits [Strasser et al., 2019]. The same seems to apply to science communication as well [Riesch, Potter & Davies, 2013]. As recently considered, the two, CS and Science Communication,

share the same challenges and, perhaps face similar limits as well as opportunities [Gascoigne, Metcalfe & Riedlinger, 2022].

Hence further research is needed, focusing on other processes that are involved in the practice of conducting research through CS and communication.

In order to contribute to this debate, this paper examines the communication strategies of CS projects. Our aim is then to offer a different entry point to explore how CS projects perform engagement through their communication strategies. Therefore, the main research question is: to what extent do CS projects design and implement communication strategies that promote effective opportunities for engagement with their target audiences? By answering this broad research question, we further address issues about who is the audience with which they make contact and which relationships these projects want to establish with their audiences through the activities developed in their communication strategy. Accordingly, this paper develops an analysis of a dedicated online survey distributed to ongoing CS projects in the EU, Switzerland, and the UK. Focusing on communication strategies as part of CS projects' architecture, it provides insights into specific communication activities within CS projects and how these can generate opportunities for engagement. In this exploratory study we consider the quadruple-helix model of innovation [Carayannis & Campbell, 2009] in order to define macro-categories of audiences that will be subsequently unpacked.

## Theoretical baselines

Despite the many different definitions offered [Haklay et al., 2021], the main feature of CS is co-operation between scientists and non-scientists; therefore, as a baseline CS requires an engagement by people who are not part of the academic community [Silvertown, 2009].

Accordingly, there is a certain consensus in considering the CS as a win-win solution [Riesch et al., 2013] to both promoting public engagement [Golumbic et al., 2017] and supporting processes of increasing scientific literacy [Oberbauer et al., 2021] across society. CS as a model of scientific knowledge production [Cohn, 2008] produces several research outputs within its own process as well and demonstrates the potential to address science communication challenges; dissemination, dialogue, and engagement should be part of the research process. Indeed, from a public engagement perspective, CS is both an aim and an enabler that links with outreach activities and science education [Magalhães et al., 2022].

A key asset of CS is the capacity to enlarge the array of actors participating in scientific research at many levels, going well beyond the non-experts' contribution to data collection. The literature in the CS debate offers many examples that cover a wide array of opportunities: defining research questions, interpreting data, providing insights for decision-making, and policy design [Bonney et al., 2009; Haklay, 2013; Hecker, Wicke, Haklay & Bonn, 2019; Göbel, Nold, Berditchevskaia & Haklay, 2019].

It is not surprising that we find CS cited as a main contributor to many aspects of Open Science. Indeed, policy documents, especially at the EU level, highly encourage CS as a practice to promote citizens' engagement in innovation [European Commission, 2018]. In fact, Open Science as a declared policy priority in

the EU's research and innovation agenda includes CS among its assets. The inclusion of CS practices can enhance the use of methods and experience that promote a properly democratic decision-making for present and forthcoming challenges [European Commission, 2020]. This supports the "democratization thesis" [Strasser et al., 2019, p. 62] of science and innovation as defined by other contributions in the debate about CS [e.g. Irwin, 1995].

CS is equally believed to offer great potential for policy-making to foster dialogue between different societal actors [Göbel et al., 2019]. As Strasser et al. [2019] found in synthesising a number of studies, one key finding is the demonstration that a specific engagement of non-professional scientists provides potentially richer and more refined scientific and ethical outcomes.

Those familiar with Science Communication and Public Understanding of Science may recognise the potential for CS in these claims that a participatory perspective is a need for science and society [Bucchi, 2008]. From this angle, the debate about CS revisits several challenges pertaining to the Science Communication scholarship; moreover, CS scholars and practitioners present this approach to steer the relationship between science and society towards an open and inclusive governance of scientific research and innovation process [Wagenknecht et al., 2021]. As shown by many scholars in STS [Wynne, 2001; Callon, Lascoumes & Barthe, 2011], a rigid distinction between science and society and roles ascribed to them is not only biased and unable to describe key processes of our times (e.g. innovation), but can reiterate forms of asymmetry and legitimacy gaps between who is entitled to make claims concerning crucial decisions about scientific research and the policy to be implemented on its basis (e.g. vaccination policies or energy transition, to cite just two among the most recent heated debates). The interaction between societal actors according to a dialogical approach [Bucchi, 2008] involves participation, mutual exchange thus overcoming the division between who is entitled to take an active role in innovation processes and the government of scientific research and technological innovation and who is not, i.e. the well-known separation labelled "Science and Society". The STS debate, together with the debate on Science Communication, contributed to reducing the centrality of such a perspective, showing that even scientific communities may fail by not considering local knowledge [Wynne, 2004] or needing the contribution of non-scientists to advance in producing new knowledge about a specific issue, as shown by seminal studies in the field of biomedicine [Epstein, 1996; Callon & Rabeharisoa, 2008]. This issue also emerges at the level of policy design for research; a group of scholars in STS recommended a closer collaboration between institutional science, research policy and broader public [Felt et al., 2007] in order to align the institutions for research governance with societal needs and define a framework for fruitful dialogue. This need for public engagement with science and technology further has come to be crucial into scientific research, thus encouraging professional scientists to experiment with communication practices designed to foster active dialogue [Engage Consortium, 2020]. In this way, the CS debate intercepts the STS literature about the construction of scientific authority and on this basis it further encourages the opportunity for non-scientists' contribution in defining research questions and research problems [Haklay, 2013].

In summary, this parallel between CS and participatory science communication presents the opportunity to consider areas of investigation that lie at a crossroads between the two debates. For instance, CS as an approach to scientific research is expected to provide access to scientific activities and foster the horizontal participation of non-scientists to fulfil the idea of engagement as a right [Leach, 2020]; therefore, we should ask ourselves if the communication strategies fulfil such a promise. In the context of an already accomplished turn towards such a participatory model encouraging practitioners to engage citizens and other societal components [Bucchi, 2008; Bucchi & Trench, 2021], this research should give visibility to key communication processes within such CS projects. On the other hand, such a right to science should offer, at least in theory, the opportunity to take part in different, and possibly multiple, stages of the research process; this may also include communication activities for those who are not taking part in data collection activities. In parallel, according to the rhetoric of CS, this could also be expected of those who already contribute to CS projects.

Precisely as envisaged by the participatory communication approach, we should expect within CS to find a two-way commitment between scientific institutions and professional scientists on the one hand, and other components of society on the other, from the beginning of a new project [Eleta, Clavell, Righi & Balestrini, 2018]. Borrowing the distinction made by the quadruple-helix model of innovation [Carayannis & Campbell, 2009] it is possible to identify potential key actors in a communication process to promote innovation pertaining to different, interconnected spheres: civil society organisations, common citizens, policy-makers and representatives of SMEs and companies. Because CS is able to engage heterogeneous actors in knowledge production processes, it is potentially a way to fulfil the goal of the participatory approach within science communication: to engage in a participatory process [Wagenknecht et al., 2021; Magalhães et al., 2022]. Nonetheless, there are some potential dangers that must be considered: indeed, social inequalities can affect the recruitment of participants and thus deepen the gap between those who participate in CS project activities and those who do not [Dopico, Ardura, Borrell, Miralles & García-Vázquez, 2021; Perelló et al., 2021]. Similarly, CS projects' leaders may not be interested in actively engaging with non-scientists [Golumbic et al., 2017] and other limits of public engagement may apply also to CS [Riesch et al., 2013]

As should be clear at this point, the communication strategies mentioned as part of CS activities may actively foster or hinder actual engagement of the participants, thereby shaping the outcomes of research through CS.

## Methods and database

We conducted a web-based survey of representatives of CS projects. The questionnaire (available https://zenodo.org/record/4836948#.ZACxwi9aZpR) was designed in English so that it could be self-administered internationally in order to reconstruct the broad continental context. This was the exploratory phase of a NEWSERA Horizon 2020 project (http://www.newsera2020.eu) dedicated to the analysis about potential integration of citizen science in Science Communication. The survey, implemented using the software LimeSurvey, was subdivided into five main areas together with an inquiry about further availability to be involved in subsequent steps of the research. The general outline is structured as follows:

a) Structural features of the project (research domain, starting year, funding);

b) Key information about main research objectives of the project and research activities carried out by citizen scientists;

c) Features linked to the engagement of citizen scientists (e.g., profile of the participants involved);

d) Channels adopted, resources deployed for their management, main communication target, and role of participants in communication activities;

e) Data policy and opinions on data use.

In this exploratory study, we considered several features to inform our analysis. We asked about the presence of a dedicated team of communicators as well as the tools to engage in participatory communication activities, both online (e.g., chats, open calls, instant messaging services) and in person (workshops, public lectures, etc.). In addition, we investigated the presence of a privileged communication target. We applied the distinction made by the quadruple-helix model of innovation [Carayannis & Campbell, 2009]. We also explicitly added journalists to this, rather than considering them as part of society at large as Carayannis and Campbell [2009] do, since, as is known from the literature, newsmakers are often among the main receivers of direct communication by researchers and research institutions [Weitkamp, 2014]. We further asked for the engagement of participants as potential communicators for creating content or disseminating it. In this regard, we also included questions about data policy regarding open access.

We investigated the communication strategies of projects active across the EU, Switzerland, and the UK until early 2021, when we closed the survey. Informed by the Hecker, Garbe and Bonn [2018] survey, to have a base list to distribute the survey, we conducted a screening activity that relied on a three-step strategy: first, we manually scanned national portals of CS networks and associations, including transnational and thematic networks along with some aggregators, such as the portal EU-Citizen.Science. We also took advantage of personal contacts in national networks in order to further push the response rate. We screened about 400 active projects between March 2020 and February 2021 covering all EU countries, Switzerland, and the UK. We invited projects to participate in the web-based survey, encouraging respondents to spread it among their colleagues and those conducting CS projects. Because of an initial low response rate, we opted to keep the questionnaire available for a longer period; due to the increased requests to fill in questionnaires during the lockdown period and to the intensive online workload, we carried out three waves.

In total we obtained 157 fully answered questionnaires. We used the IBM SPSS 27 package to analyse the collected data. In this work we will focus our analysis on three emerging national contexts in the area of CS, namely Spain, Portugal, and Italy, that are currently less visible in the international debate [Pelacho, Ruiz, Sanz, Tarancón & Clemente-Gallardo, 2021] and for which very little analysis and information exists.

The number of considered questionnaires may vary depending on the answers, since some respondents chose the alternative, "Don't know," or the residual category, "Other, specify."

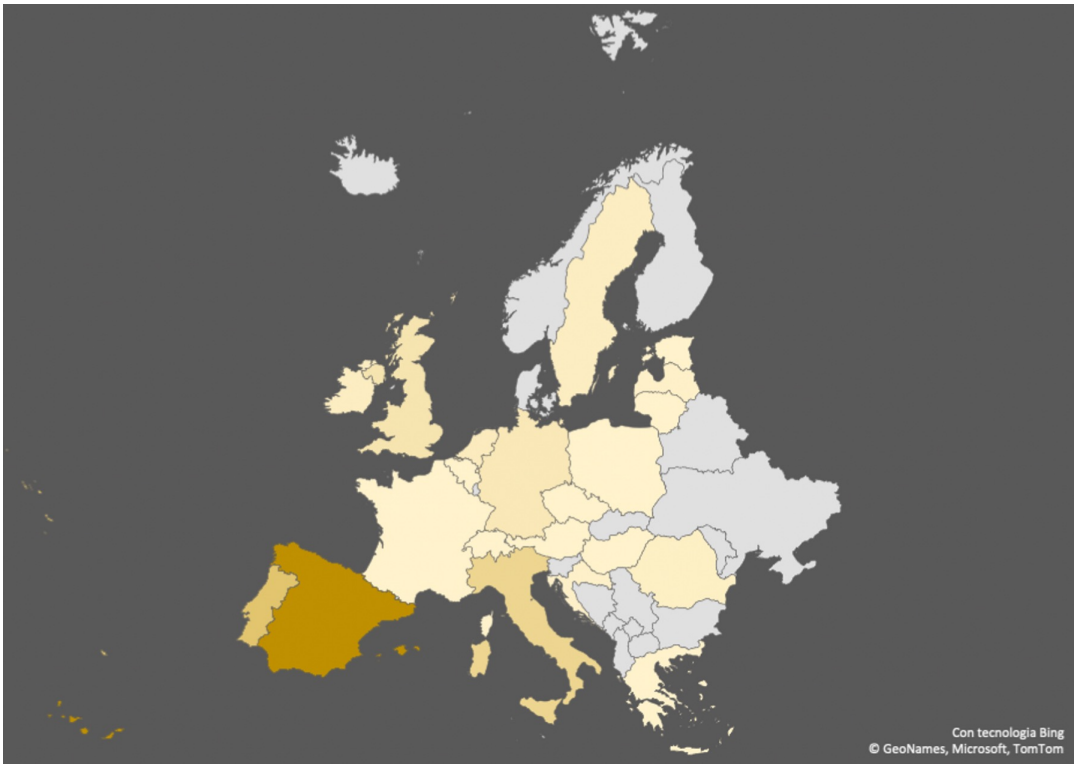


**Figure 1**. Geographical distribution of projects surveyed from European countries in EU-28, the UK and Switzerlan (n=157). Yellow ochre intensity indicates the concentration of projects. Grey indicates no projects.

As visible in the Figure 1 map, the majority of replies came from projects in Spain (37%), Portugal (17%), and Italy (11%). Other countries, typically among the most active in CS, such as the UK, Germany, and Sweden to name a few, were under-represented. As such, we covered a blind spot since previous attempts to survey CS projects in the EU had a poor response rate from Southern European countries [Hecker et al., 2018; Vohland et al., 2021] although they are growing communities [Vohland et al., 2021]; therefore, the make-up of the surveyed projects allows us to make further comparisons between the three main national groups and the rest of Europe plus the UK, adding the variable of three newcomer countries to CS.

## Results and discussion

In general, the respondents to our survey offered a good overview of their activities within the projects: most were project coordinators (52.2%) or managers (14.9%), while only 9.3% of respondents defined themselves as researchers. Regarding the research areas of the surveyed projects, we obtained a picture similar to other studies [e.g. Kullenberg & Kasperowski, 2016]: indeed, the most represented domain was environmental issues (66.5%) and, more specifically, biodiversity (35.6%), while the field of citizen social sciences was underrepresented, comprising only 2.7% of the total. Concerning further structural variables, the surveyed projects were quite recent at the time of data collection: 65.6% of them was just four

years old, with more than one out of three being brand new projects that started in 2020. Nonetheless, 18.5% of the projects are long-lasting (i.e., ten years old or more); among them, more than half (11.46% of our sample) were governed by NGOs. Projects led by universities and research institutions, on the contrary, tended to be more recent (less than four years old), corresponding to 44.58% of the total. We infer, then, that institutional science growingly embraces CS as an approach to contribute to scientific knowledge creation, at least in the EU, Switzerland, and the UK.

Within this context, we investigated what CS projects are doing in terms of communication strategies in order to understand to what extent CS is already promoting participation through a dialogical relationship with different societal actors.

We will describe the communication features of projects in relation to other recorded variables, such as structural features (age of the project, country in which the project is based, type of funding), and in connection with the experiences of other surveys and monitoring conducted in the past.

### *4.1 Communication channels chosen: communication preparedness*

We recorded a marked preference for social media as well as the array of features possible on websites. We extrapolate a portrait of the surveyed projects as being well-equipped with tools for interacting with their audience. This is one side of the coin that we can call communication preparedness. Generally speaking, the projects showed a preparedness deploying a media apparatus, investing resources in self-promotion through digital communication channels much more than through non-digital or more traditional ones. Such preparedness seems to be furthermore inclined towards interactive tools.

The importance of digital technologies for communication stands out due to the high number of the CS projects surveyed using social media: 85.3% of projects claim to have at least one social media account and about 33% have three or more accounts. As reported by Science, Media, and the Public Research Group (SCIMEP) [2016], scientists tend to use Facebook and Twitter on a daily basis for scientific-related activities (consulting and publishing); other studies confirm the centrality of Twitter as a key social media for dissemination and networking [Pavelle & Wilkinson, 2020; Liang et al., 2014]. The CS projects that replied to our survey are in line with this. We further recorded that the surveyed projects typically have a website (85% of the total), often including at least one of the following features: a FAQ section (38%), open calls/webinar services (34%), a forum (21%), and a chat feature (13.3%). Surveyed CS projects use or include social media as part of their advertisement strategy; indeed, through our questionnaire, we recorded the use of social media as the main way to publicly promote the projects (41%), which was more than other more traditional media, such as radio or TV (22%) or newspapers (25%). Moreover, most of the projects that invest in a single medium for advertisement (37 out of 50 cases) have an account dedicated to social media. This trend might have many reasons, such as free accessibility and ubiquity, making social media more successful compared to other communication paths.

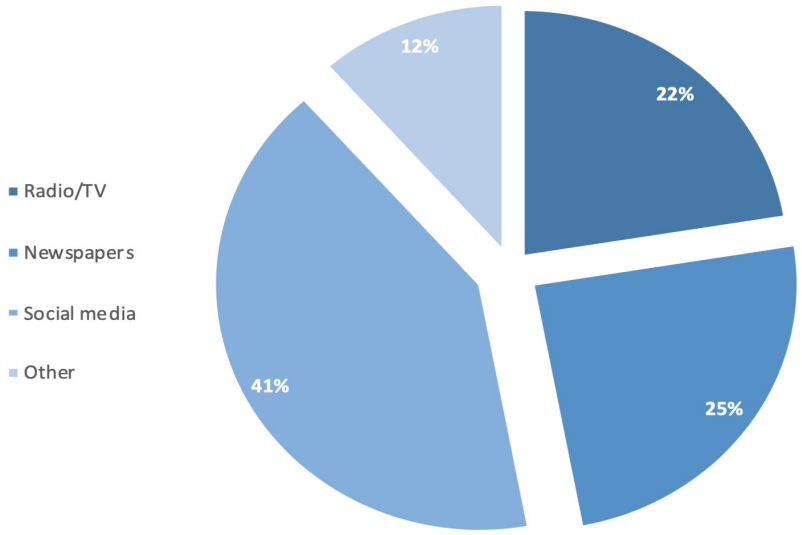


**Figure 2**. Advertisement channels for CS projects as reported by respondents (n=157).

We determined that there is personnel dedicated to social media management: specifically, 22% of the projects have a social media manager. This echoes the high rate of projects that have at least one member of staff with some kind of training in Science Communication (63%). We did not record specific differences among countries, although the subgroup of Spanish projects has the highest rate of social media managers (21 out of 60 projects). Nonetheless we have no evidence about the actual contents shared and the level of engagement of projects. In one case out of three, a staff member holds a master's degree in Science Communication, a fact that confirms the preparedness but as pointed out by the literature this does not ensure a proper engagement with non-scientists or general public [Kouper, 2010; McClain, 2017]. This matches with a limited use of potentially two-way communication tools, such as instant messaging (WhatsApp or Telegram groups). Sixty-one percent of projects do not have one communication tool specifically for connecting with participants, regardless of the sub-groups. This current state of affairs leads us to affirm that, in general, CS projects are investing in digital media communication as a relevant part of their activities.

### *4.2 The role of participants in communication actions within CS projects*

Besides preparedness, we investigated the activities of citizen scientists in communication actions within CS projects in order to explore their role: are they recipients of communication or active contributors (i.e., ambassadors)? We tried to understand what participants are asked to do in terms of communication generally, and more specifically with regards to communication within the projects in which they took part. As it is well known, most of the CS projects follow a kind of contributory approach [Bonney et al., 2009] embodying an "engagement by doing", as the main task for participants is providing data. Hecker et al. [2018] noted that the most common way of engaging is to ask citizen scientists to contribute by accomplishing easy monitoring tasks or data collection, following specific instructions or through applications. Our data confirm this trend: 65.5% of projects require participants to perform monitoring activities or, occasionally, report some specific observation about phenomena. This percentage far exceeds the share of CS

projects that request participants to disseminate the research results and activities; less than half of the projects (44.9%) invite participants to take part in active communication actions and only 14.7% do so regularly. This is independent of the project's age, the scientific domains, the leading organisation, the funding scheme that the project may benefit from, and even the presence of a staff member with some training in science communication. The main difference occurs between different countries: in Italy and Spain, one in four projects proposes that participants disseminate the results of their activities, while the Portuguese projects do so in less than one case out of ten, like the other countries surveyed.

### *4.3 Preferred target audiences in CS projects*

Projects rate citizens in general (or society at large) as the main communication target. As can be seen in Table 1, all subgroups agree on the importance of citizens in general as the most relevant communication target, immediately followed by educators. Moving towards the goal of science communication in CS projects, there is a certain consensus that the opportunity to use data from CS projects to influence policy-making is the lowest important aim, which has already been signalled in the literature [Converse, Shaw, Eichhorst & Leinhart, 2016], although there have been recent developments in this field [Göbel et al., 2019]. Three out of four subgroups agree that data primarily serves to create databases for scientific research.

| | Spain (n=55) | | Portugal (n=23) | | Italy (n=18) | | Other countries (n=49) | | Total (n=145) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M. | S.D. | M. | S.D. | M. | S.D. | M. | S.D. | M. | S.D. |
| **Citizens in general** | 4,64 | 0,868 | 4,61 | 0,656 | 4,44 | 1,097 | 4,41 | 0,956 | 4,53 | 0,898 |
| **Schools, educators *** | 4,38 | 0,933 | 4,43 | 0,728 | 4,11 | 1,278 | 3,69 | 1,446 | 4,12 | 1,184 |
| **Journalists/communicators** | 3,98 | 1,08 | 3,87 | 1,217 | 3,44 | 1,294 | 3,82 | 0,95 | 3,84 | 1,091 |
| **NGOs (associations, fundations, concerned communities, etc.) *** | 4,15 | 0,951 | 3,78 | 1,166 | 3,22 | 1,114 | 3,69 | 1,065 | 3,82 | 1,078 |
| **Policy Makers** | 3,73 | 1,433 | 3,78 | 1,313 | 3,61 | 1,461 | 3,67 | 1,313 | 3,7 | 1,365 |
| **Universities, professional scientists *** | 3,95 | 1,044 | 3,65 | 1,152 | 2,94 | 1,305 | 3,47 | 1,192 | 3,61 | 1,18 |
| **Industry and SMEs** | 2,8 | 1,311 | 3,04 | 1,461 | 2,39 | 1,145 | 2,29 | 1,323 | 2,61 | 1,339 |

The importance, on a scale from 1–5, assigned to each communication target according to the project's objectives (n=145).
*= relevant difference between national groups based on F value for ANOVA. Green represents the highest value on a scale of 1–5 about mean (M.) and lowest value on Standard Deviation (S.D.).

**Table 1**. Opinions About Communication Targets.

It seems clear that there is lesser consideration for other important categories of stakeholders. Other potential important targets are judged, on average, as being less relevant than the main target audience. Among them, we find industry scoring the lowest value. Journalists who may contribute to giving an account of CS research paths, perhaps even promoting those experiences, look less relevant for the surveyed projects. In this regard as well, there are no significant differences among the age of the projects, research domains, or funding schemes. We recorded some differences among countries in judging relevance of "schools and educators" and "NGOs" as potential target audiences; apparently it depends on the leading organisation, but there is no statistically demonstrable reason for that. It may be

reasonable to consider the promise of increasing scientific literacy, as is often reported in the literature about CS [Strasser et al., 2019; Bonney, Phillips, Ballard & Enck, 2016]. This is possibly the clearest match between a specific approach of Science Communication and public communication of science with CS; it can be argued that the same dimension of education in science is addressed by concentrating on schools and educators in order to integrate a practical activity for pupils and students [Lewenstein, 2016].

### *4.4 Discussion*

We explored different facets of communication. We considered projects as our unit of analysis through answers from their spokespeople, such as communication channels, the role of participants within the projects and more specifically in communication, and the use of data. In a sense, we investigated what projects concretely do and considered their structural features, such as the project's age, funding source, and the country where a project leader is based. In this regard, the data set is geographically distributed unevenly across countries: the largest number of projects we considered were from three southern European countries (Italy, Portugal, and Spain). Although it may sound like a limitation, it offered a two-fold opportunity: first, it allowed us to compensate for the tendency in the literature to favour British, North American, and Northern European CS experiences and to compare the three with the broader context; second, it gave an account of three countries that see a growing CS community.

According to our analysis, projects tend to reproduce more canonical styles of communication based on the separation between scientists and non-scientists regardless of the country. In this sense, our findings of the main categories through which CS projects orient their efforts are interesting: the categories rated the lowest are those normally addressed less by the promises of CS, but nonetheless are relevant in an RRI framework, such as industry, policy-makers, and universities/professional scientists. At the same time, the declared preference for citizens as the main target and the social media strategies evokes the scenario of a communication that is mainly oriented towards educational purposes, as already noticed [Irwin, 2001].

This may limit the outcome of a potentially engaging activity promoting proper encounter as mainly oriented towards a top-down stream of contents for non-experts. Furthermore, our surveyed projects echoed the tendency to engage participants mainly as data collectors, thus keeping the participation to a basic level. This seems to be equally distributed across the different structural features that we considered (age of the project, country in which the project is based, type of funding).

According to the data shown so far, we find some ambivalences. We first learned that there are some tendencies linked to the choice of specific channels that potentially may drive towards a direct encounter between professional and non-professional scientists. This is further supported by the finding that many projects invested in staff with some kind of training or duties in communication (social media managers and trainees in Science Communication). Therefore, we cannot exclude the possibility that surveyed projects are open to a participatory

approach. On the contrary, the preference for social media may point to communication strategies oriented towards a more engaging approach with the audience. Indeed, the large majority of projects have a website with many features used to interact with their audience. Hence, this bolsters a deployment of potentially engaging communication technologies that we call digital preparedness to communication, mainly characterised by choices that are oriented toward the opportunities promoted by digital technologies for a mutual exchange through communication and further enriched by staff with some training in the public communication of science. On the other hand, social media is mainly used as a tool for promoting a project.

Analysing the data, we asked ourselves whether the communication practiced by CS projects may hinder or support engagement. Indeed, taking all these findings together, we find that the CS projects surveyed tend to interpret communication as a disseminating activity, rather than as a tool to promote proper encounter based on communication with both participants and other potential target audiences. We recorded limited opportunities for participants to become ambassadors of the project in which they collaborate. As the project's spokespeople replying to our questionnaire declared, participants are not often asked to spread the contents of their activities; rather, they tend to mainly be engaged in monitoring and data collection activities, thereby keeping the potential level of engagement quite low. This fact echoes the most common targeted audience we recorded: the broader public or the most likely recipient of scientific notions such as students. Such an undefined target audience further highlights a conception of public communication of science quite far from being part of a strategy for active engagement or, at its best, as accomplishing an educational aim. The most striking element is the absence of a significant difference between national groups as well as the overlap between leading institutions. Whether a project is led by an NGO or a university does not significantly affect the trends recorded. It further appears to be a general feature regardless of the country in which the project is based, whether it is a country with an older tradition in CS or not. It could be said that this seems to present a repurposed top-down, one-to-many, unidirectional and oriented to a knowledge transfer science communication style.

## Conclusion

Discussing CS communication strategies may open up a discussion of broader issues of the relationship between science, technology, and society in our contemporary context.

In outlining shared elements between CS and participatory science communication, we further focused on CS as a way of conducting scientific research that is not meant to be exempt from institutional drives towards public engagement and communication. This occurs, for instance, when drafting research proposals that are expected to meet requirements of impact through activities linked to public engagement. Therefore, we emphasised a two-levels parallelism, conceiving CS as a way of conducting research and as an engaging way of doing science for non-professional scientists. These elements taken together point to the communication strategies of CS projects as a field that deserve some attention for the CS debate, and perhaps beyond it, thus calling for empirically informed reflection. As case studies have shown us, participants in CS have a blurred role as ambassadors and, at the same time, recipients of science communication: that is

why CS projects themselves should take into consideration what is required for effective participatory science communication [Wagenknecht et al., 2021]. Considering these challenges, our contribution highlighted how widespread is the reproduction of educational aims for the general public in CS projects.

It was shown that CS projects lead by professional scientists (as well as by NGOs) tend to not perform to engagement in a participatory way in what we called communication preparedness through digital channels. This resonates with previous findings in the literature of Science Communication [Kouper, 2010; McClain, 2017] as well as in CS [Golumbic et al., 2017], further confirming that the challenges and limits of public engagement are not yet overcome or solved [Riesch et al., 2013] even with a promising engaging approach such as CS, further confirming the common challenges with Science Communication [Gascoigne et al., 2022].

According to our findings, well-known criticalities and limits (i.e., talking the talk not doing the walk) about public engagement still hold, but our exploration at the international level has only scratched the surface. Focusing on the activities of participants in CS projects, communication channels, and target audiences is a starting point for mapping out how CS projects interpret the role they play in the relationship between science and society. This seems especially relevant since this is clearly visible in southern countries, considered as emerging in CS, and other countries with an older tradition.

This state of affairs opens further questions that our questionnaire could not answer. Therefore, additional research should focus on how communication is performed in practice and what contents are shared. When considering the criticism of the way that public engagement is performed and the inconclusive outcomes of CS, it might be worth considering other research tools based on both social media and techniques that involve target audience as part of the communication process itself.

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## Authors

Paolo Giardullo (corresponding author), is a assistant professor at University of Padova, Italy. He works at the intersection between Science & Technology Studies and environmental sociology. He did research about public communication of science and technology. More recently he is matching his interest in the study of algorithms and platforms with processes of participation into Citizen Science. In dealing with these topics, he applies mixed methods research in connection with the digital methods approach.

paolo.giardullo@unipd.it

Federico Neresini, is full professor in Sociology and focuses his interests on technoscience through Science & Technology Studies perspective. More specifically he is interested in the construction processes of scientific knowledge and in analysing technoscience in the public sphere.

federico.neresini@unipd.it

Esther Marín-González holds a Ph.D. in Biology and Plant Biotechnology from the Autonomous University of Barcelona, a MA in European Studies on Society, Science and Technology, with a specialization in Governance, Innovation, and Sustainability, from Maastricht University, and an MSc in Scientific, Medical and Environmental Communication, from Pompeu Fabra University. Currently, she is a WP coordinator in the EU project ENJOI (Engagement and Journalism Innovation for Outstanding Open Science Communication), and a researcher in NEWSERA.

emgonzalez@fc.ul.pt

Cristina Luís holds a PhD in Biology and is a researcher and lecturer at the Faculty of Sciences, University of Lisbon, in the areas of science communication and citizen science. She belongs to the Interuniversity Centre for the History of Science and Technology (CIUHCT) and is part of the team promoting the implementation of the Portuguese Citizen Science Network. She coordinates a research project that aims to document the history of citizen science in Portugal.

cmluis@fc.ul.pt

Joana Magalhães is the Project Coordination Manager from NEWSERA. She holds a PhD in Biochemistry and Molecular Biology, funded by MSCA and a postdoctoral fellowship from CIBER-BBN, with more than 15 years experience in health sciences, science communication from a gender perspective and public and patient involvement. She is the recipient of Science at Stage 2017, Category Press, TV and Radio. She is a Board Member of the Spanish Association of Women in Science and Technology - Galician Node.

joana.magalhaes@scienceforchange.eu

Rosa Arias is the CEO and Founder Science for Change. Arias is a Chemical Engineer and MSc in Energy. Arias is the creator of the citizen science App OdourCollect aimed at building collaborative odour maps based on citizen observations. She is the coordinator of the NEWSERA project, with the main goal of integrating citizen science in science communication and the coordinator of the Catalan Cluster at TRANSFORM. She is a member of the Science at the Spanish Parliament Initiative.

rosa.arias@scienceforchange.eu

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