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Towards open science in Argentina: From experiences to public policies

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Abstract

The emergence and wide diffusion of information and communication technologies created ever increasing opportunities for sharing and collaboration, which shortened geographic, disciplinary and expertise distances. There exist various technologies, tools and infrastructure that facilitate collaborative production processes in various social spheres, and scientific production is not an exception. Open science produces scientific knowledge in a collaborative way, including experts and non-experts and to share the outcomes of knowledge creation processes. We identify 68 open science initiatives in Argentina using different primary and secondary sources. This paper describes those experiences in terms of goals, disciplines and openness along research stages. Building on the relationship between characteristics of openness and expected benefits, we discuss policy implications in order to better support openness and collaboration in science.

Contents

1. Introduction

Information and communication technologies (ICTs) are creating great opportunities for facilitating, expanding and accelerating processes of collaborative production in various social spheres, and scientific production is no exception. New technologies and new practices such as big data, machine learning, massive use of sensors, drones, and the greater availability of low-cost scientific tools are transforming the production of knowledge. There are platforms of open data and publications, open educational resources, and Web sites that facilitate collaboration by shortening geographic, disciplinary and expertise distances. Although most collaborative practices in science are online, there are others that are not necessarily performed through that medium, such as participatory research-action [1] or science shops [2].

In this paper, we define open science as producing scientific knowledge in a collaborative way, including experts and non-experts while making intermediate and final results obtained in this process freely available. Collaboration and openness are found in different stages of the research cycle.

The adoption of open science practices permits the reclaiming of an old ethos of the production of scientific knowledge as the production of public and universal goods, generating a series of associated benefits. First, open science improves the efficiency in scientific production. On the one hand, increased collaboration avoids unnecessary duplication of efforts and facilitates the use of a common stock of knowledge and of cognitive resources (Bartling and Friesike, 2014). On the other hand, the possibility of inviting a variety of actors, whose cognitive ability and time have previously not been available to scientific production, amplifies processes of collective intelligence (Benkler, *et al.*, 2015). Second, citizen participation not only increases resources, but also contributes to the democratization of knowledge democratization (Wiggins and Crowston, 2011). Finally, by opening up and collaborating with society, scientific production could address issues of social relevance more effectively (Masum and Harris, 2011; Nielsen, 2012). Some even suggest that the benefits of open science mark the beginning of a revolution in the production of knowledge (Bartling and Friesike, 2014).

Recently, those attractive claims have raised the interest of scientific institutions, funding agencies, and policy-makers worldwide [3]. In Argentina, Law 26.899 of Open Digital Repositories, enacted in 2013 [4], is also indicative of the interest that local scientific policy has in practices of open science. However, it is not yet clear what resources and capabilities are available for open science in the country nor what the most promising directions for openness and collaboration are.

In a previous study, we analyzed data obtained from a survey distributed to researchers of the national scientific system (to which 1,463 researchers answered), to assess the scope of open science in Argentina [5]. Two key findings should be noted from this study. First, both the concept of "open science" and the associated practices and hence also its benefits and implications are not very well known by the local scientific community. While distributing the survey, we provided a definition of open science and offered more information online to internalize the concept. However, many actors described traditional qualitative training and outreach activities or methodologies (*e.g.*, interviews, workshops, focus groups, etc.) for collecting primary information in the social sciences or when social actors are the main informers. Second, with a greater or lesser extent of commitment and knowledge about open science, a very high proportion of the researchers demonstrated interest in the survey. For example, they took the time to answer in detail to the only open question on the survey. We also found differences by disciplines and field of application, since the type of practices, which are functional in every case, can also vary. We believe that the fact that so many of the surveyed researchers considered some of their research practices to be open science, illustrates that some scientists in Argentina are familiar with openness and collaboration. This could favor the diffusion of new practices, some of which might be more intense or radical in terms of openness.

The survey points towards a great potential for policies promoting open science in Argentina. For many researchers moving towards a greater commitment to openness would probably involve delving more deeply into some elements of their usual practices. A key challenge is how to transmit not only what open science is or how it is understood in other places, but also to discuss the benefits, challenges and risks involved. There is plenty of room for moving forward in this direction. A first step could be to provide greater visibility to those projects that are already committed to openness in science and to promote their updating, expansion and replication. This paper provides some initial steps in that direction.

Here we characterize in some detail open science experiences using case material that was obtained in our initial survey as well as some other cases that we identified additionally. For this paper, we checked secondary sources to see if the identified initiatives truly fit our definition of open science. We found altogether 68 national open science experiences. In theis paper we discuss their objectives, disciplines and degrees of openness. Based on this analysis and building upon previous work of our team, we present some policy implications in order to encourage openness and collaboration in science in Argentina.

The following section presents the conceptual framework that we used to define open science. Section 3 presents our methodology and section 4 provides an analysis of the information obtained. The final section treats policy implications of our findings.

2. The conceptual origin of open science practices

In modern scientific tradition, the production of knowledge results from a balance of two opposing forces: *competition* and *collaboration*. Competition between scientists is oriented towards obtaining priority in the production of new knowledge (Merton, 1957), which increases the probability of finding solutions because various actors are simultaneously in the process of solving a portfolio of cognitive problems. Meanwhile, collaboration between scientists from different disciplines and generations allows knowledge to advance cumulatively, "on the shoulders of giants" [6]. It thus avoids the necessity to re-invent all knowledge every time that a new problem is addressed, because new knowledge is always based on the knowledge to which others have previously collected and distributed.

In a Mertonian perspective, modern science is governed by four principles that guide the actions of scientists and achieve a balance between forces of collaboration and competition to the overall benefit of scientific production (Merton, 1977; Orozco, 2010). These principles are:

- *Communalism*: Scientific discoveries are common property, where scientists exchange their rights of intellectual property for reputation and recognition;
- *Universalism*: The reliability of scientific claims are evaluated on the basis of universal criteria, offering no room for the discretion or discrimination associated with personal characteristics of the scientists proposing them (*e.g.*, gender, race, nationality, religion);
- *Disinterestedness*: Scientists contribute to the stock of common knowledge without expecting any reward other than scientific reputation; and
- *Organized skepticism*: To be considered valid, ideas must be tested and are subject to the norms of scrutiny in a respective scientific community.

However, in practice, traditional science has been much more closed, much less universal and more upright and corporate (*e.g.*, some individuals and institutions have more authority than others to 'value' findings) than the manifested ideal of communality suggests. For correctly adhering to the criteria of validity that are established within ever more specialized scientific communities, science is at the same time also increasingly focused and endogenous in the selection of its problems.

This is the result of three phenomena. First, the incentive scheme, which relies heavily on measuring the quantity of publications obtained over a period of time, favors competition to the detriment of collaboration (Hagstrom, 1974; Stephan, 2010). Scientists often expose a part of their methodology and data, but much of this knowledge is retained, either because of fear of competition or the intrinsic characteristics of the tacit knowledge involved. Thus, although scientists publish their results, much of the relevant information to be able to construct knowledge cumulatively is not completely disclosed (Franzoni and Sauermann, 2014). In addition, publishers of scientific publications often impose restrictions on access to scientific knowledge (Wagner, 2008). As a result, so-called traditional science has been increasingly exposed to a process of reduced collaboration and less communalism.

Second, the publishing market fostered corporatism and fragmentation in science. The concentration of the publishing market established a regime of hierarchy among scholarly journals, conditioning the schemes of incentives that regulate scientific work, and contributing to the fact that scientific production became increasingly corporate and fragmented. On the one hand, demanding standards of scientific membership associated with the quality of publications were established. On the other hand, scientific production became more fragmented by following research priorities defined in a very limited scope of each discipline and promoting excessive specialization. This specialization distances scientific results from those that are of public interest and whose social value is limited to generating scientific knowledge as an end in itself. In developing countries, this attitude has been called "scientism" (see, for example, Varsavsky, 1969). In practice, it implies the subordination of research to international and non-local agendas (Kreimer, 1998).

Finally, scientific policies were oriented towards the commercialization of scientific knowledge. From the 1960s on, pressures emerged from the political arena of some countries for science to demonstrate its social and economic utility (Mowery, 1995; Nelson, 2004; Dasgupta and David, 1994). To promote the productive application of scientific knowledge, the interference of intellectual property mechanisms in the protection of scientific knowledge that previously remained in the public domain was amplified in the 1980s (Mazzoleni and Nelson, 2007). Thus, scientific public policy added the market as a factor to revitalize scientific production. This accelerates the processes of greater occlusion of science, conditioning scientific investigations to areas that are of interest to the market, fomenting the private appropriation of the benefits of scientific production. It also entails that not all scientific findings can be published because of confidentiality clauses. A system of intellectual property demands that inventions not to be published in the public domain, otherwise they could not be patented.

In this context open science practices seek to reverse these processes of enclosure, corporatism, disciplinary fragmentation and private appropriation, through (i) targeting the production of open public goods; (such as data, publications, infrastructure and tools amongst others) that are available to all; (ii) fostering greater collaboration between scientists from different disciplines and academic fields; and (iii) broadening the diversity of actors producing science.

Open science is the result of a long process of experimentation with open ways of producing knowledge that has reached a turning point with the emergence and diffusion of ICTs (Gagliardi, 2015).

Some of the practices of open science, such as citizen science, have a long history [7]. This practice is oriented towards both facilitating the scientific work because it invites the general public to participate in the generation of information relevant to scientific research, as well as diversifying knowledge sources and democratizing their production by involving amateurs as well as experts of certain topics in scientific production.

Other practices, such as participatory-action research and alternative science (Hess, 2007; Martin, 2006; Moore, 2006), date back decades ago. They encourage the production of knowledge driven by social needs and experiment with opening the research agenda as a response to the processes of corporatism and fragmentation.

The current open science movement builds upon these traditions and is inspired by the open and participatory practices developed by activists involved in free software and open source. Similar to *open source* practices, various practices of open science are seeking to share data, publications and problems by using social networks and digital media. This opens up the possibility of creating open forms of collaboration between scientists in defining problems and research lines (*e.g.*, in the Polymath Project at https://polymathprojects.org) (Nielsen, 2012), or for allowing citizens to participate in the characterization and analysis of data (*e.g.*, Galaxy Zoo at https://www.galaxyzoo.org, Foldit at http://fold.it/) (Franzoni and Sauermann, 2014) or in the design of open source scientific software and instruments (for example, R statistical software, https://www.r-project.org) (Pearce, 2012). The key point in the process is the open and free publication of research results. Originally, this process involves the publication of scientific *papers* in open repositories, although progressively open repositories of data have also been developed (Gagliardi, 2015).

Some recent opening practices have their origin in specific incentives of public policy, generally promoted by international organizations fostering scientific production (Franzoni and Sauermann, 2014). For example, it is increasingly common for scientists from different laboratories to collaborate on the use of certain infrastructures, technologies and research resources that originated from an investment of public funds. In general, funding agencies have shown increasing interest in encouraging the common use of instruments that require significant investment (Sonnenwald, 2007).

Table 1 summarizes the main features of most common international science practices and identifies some examples.

Table 1: Most common international open science practices.

Name	Description	International examples
Open access	Online publication of articles and other forms of knowledge or scientific	The Directory of Open Repositories registers a total of 3,048 repositories worldwide, of which 267 are located in South America. In the region, there are the SciELO- Scientific Electronic Library Online, Redalyc: the Network of Scientific

	information in an open and free way. In 2003, a group of academics signed the Open Access Initiative in Budapest promoting the self-archiving of scientific articles and the creation of open access journals. Other similar statements followed.	Journals of Latin America and the Caribbean and the Network Reference.
Network science	Networked science uses Web tools, social networks and open access to increase the scale (and diversity) of collaboration and accelerate the production of scientific knowledge. It seeks to promote exchange, mainly between scientists but also with other actors, both intermediate and final products as well as ideas.	Open Science Framework
Citizen science	Collaboration between scientists and citizens, mainly in the data collection stage, which allows to especially expand the capacity to generate large databases. It is a widespread practice in ecology and astronomy.	Galaxy Zoo Great Sunflower Project
Science for people	Scientific groups that seek to generate knowledge or tools for solving concrete problems of civil society.	Science shops in the E.U.
Dissemination of science	Practices that seek to disseminate scientific knowledge to the broad	Fucking love science (originally a Facebook page at https://www.facebook.com/IFeakingLoveScience, is a site maintained by Elise Andrew, which reached almost 20 million likes in January 2015; SciShow (at

	public [8]. This involves using communication channels of scientific results that are different to the traditional ones, such as social networks, blogs and science clubs. And also new communication formats, such as infographics, notes and videos, but also more interactive ones such as games and museum activities.	https://www.youtube.com/user/scishow, a Youtube.com scientific news channel)

3. Methodology

In May 2015 we conducted a survey from an online platform using a questionnaire of only four questions e-mailed to about 18,500 scientists in the public domain. We obtained 1,463 valid answers and among them 70 percent answered the only open field of the survey, in which we asked them to describe their most relevant open science experience.

We read these entries and identified about 70 that had the potential of truly being open science experiences. We complemented the information provided in the survey with another one that we obtained from secondary documentation and interviews to be able to verify that they were indeed open science experiences, as defined in this paper. In this process we discarded some of the experiences for not matching our definition, and also incorporated new cases of open science that we identified later. In particular, we included all data repositories and national publications that are affiliated with the System of Libraries and Information (SISBI, at http://www.sisbi.uba.ar).

4. Analysis of open science experiences in Argentina

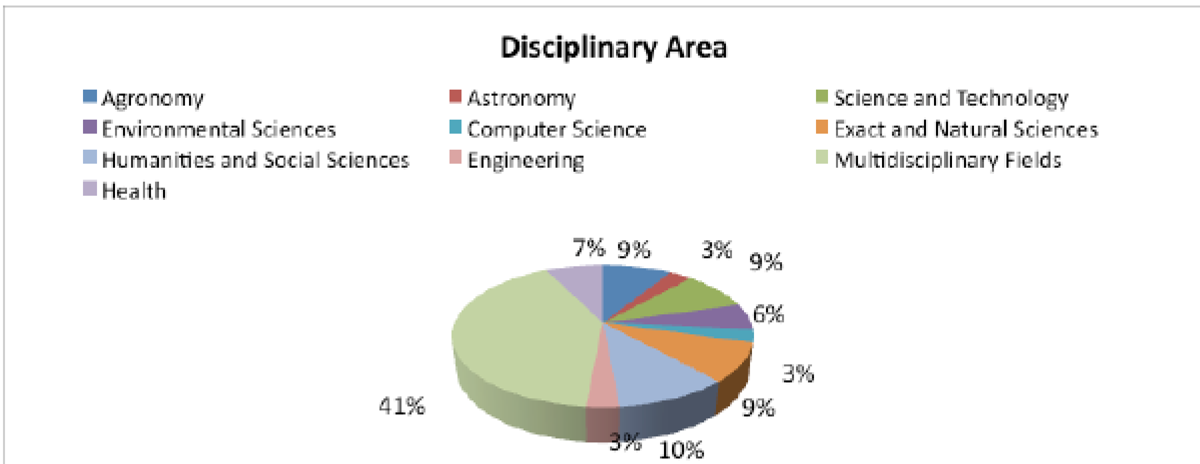

Figure 1: Open science experiences by disciplinary area.

As shown in Figure 1 of the 68 open science cases surveyed, the highest frequencies are found in multidisciplinary fields (41 percent) [9], humanities and social sciences (10 percent), exact and natural sciences (nine percent); followed by science and technology (nine percent), agronomy (nine percent), health (seven percent) and environmental sciences (six percent), and to a lesser extent in computer science and engineering and astronomy (three percent).

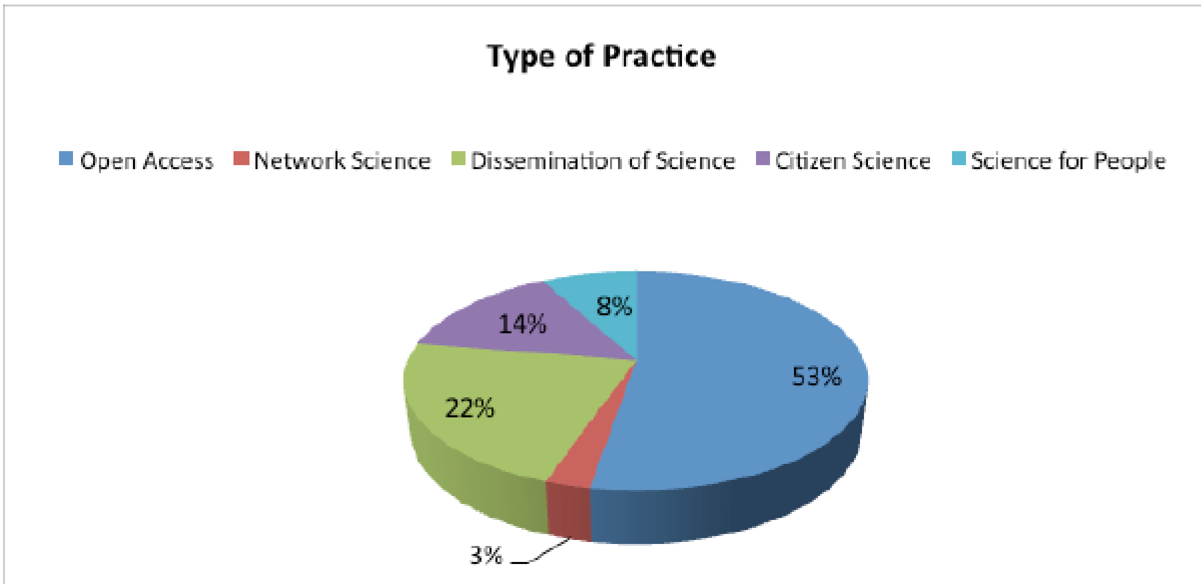

Figure 2: Open science experiences by types of practice.

Several different open science practices mentioned in Table 1 were pursued by the 68 initiatives. More concretely, we identified 88 practices: 53 percent of them are of *open access* (data repositories and national publications), 22 percent are cases of dissemination of science, 14 percent of the cases involve practices of *citizen science*, followed by eight percent of practices of *science for the people* and only three percent *network science*.

At the intersection of type of open science practice and knowledge field, we find that in the *dissemination of science*, the area of *science and technology* provides the largest proportion (22 percent), followed by *humanities and social sciences* with 11 percent. In the area of *science and technology*, we can mention the example of the "Science Mate" as a model of meetings open to the community aiming to publicize the scientific work that occurs in a region and to contribute to the social appropriation of knowledge by bringing the researchers' experience directly to the people. Linking specifically *open communication* and exchanges with *students and teachers*, "Scientists go to schools", is an example of an initiative promoting the interaction between scientists and teachers in enriching science classes, through collaborative projects.

The range of projects belonging to the humanities and social sciences expands from cases using radio, television or computer networks to provide broad and diverse dissemination, to others, such as the "Travelling Museum." This "museum" is a mobile facility of the Museum of Anthropology at the National University of Córdoba, designed to expose different audiences to anthropology.

Continuing with the *dissemination of science*, we find two cases of food sovereignty in agronomy: the "free chair of food sovereignty" of the National University of La Plata as well as part of the Faculty of Agronomy of the University from Buenos Aires. Both aim at generating a public space of awareness and formation.

All cases of *dissemination of science* involve the community in general terms, with some variants of specifications by groups such as the *community of children* for those of school age.

Concerning *citizen science*, we identify projects of the environmental sciences (22%), of humanities and social sciences (20 percent) and, to a lesser extent, of *astronomy, exact and natural sciences*, multidisciplinary fields, computer and engineering sciences (10 percent per area). In the area of *exact and natural sciences*, "eBird Argentina" (http://ebird.org/content/argentina/en/) that uses a platform of data collection so that users can report their observations. This information provides details on the spatial distribution of species, allowing monitoring of population trends, identification of areas or of important sites for bird conservation, and contributing to the design of better management or recovery plans for threatened or endangered species.

In *multidisciplinary fields*, we mention the case of Territorial Intelligence, a project of integral territorial management that studied, along with neighbors and institutions, the vulnerabilities of two zones of the cities of La Plata, Berisso and Ensenada that were affected by flooding. The team coordinated diverse techniques of the exact and natural sciences with methods of the social sciences, and with the contributions of citizens, scientists, politicians and entrepreneurs, it managed to co-design three agendas of management of specifically social problems.

In *environmental sciences*, we find the case of “Co-sensores” whose intervention strategy is based on the notion of participatory research for co-producing knowledge. It combines scientific practices and knowledge with communities’ knowledge and practices. Also, astronomy is active in practices of citizen science. We mention the example of “Citizen astronomers” where citizens participate on a data collection platform in the recording of astronomical data based on the simple observations of the night sky.

In *science for people*, the highest frequency of cases is concentrated in agronomy (50 percent), followed by health with 17 percent, another 17 percent in multidisciplinary fields and 16 percent in environmental sciences. An interesting case belonging to the health area is the one of the “Sanitary Camps of the Chair of Socio-Environmental Health of the National University of Rosario”. It is an initiative of the medical school of the University of Rosario. It has the dual objective of training future graduates in medicine while generating, in coordination with authorities, social organizations and the neighborhoods of the villages surveyed, epidemiological data on morbidity and mortality of rural populations. These and other groups have used the generated data in dissemination activities about the health effects of agrochemicals used in agricultural production and of other environmental pollution factors.

In several of the cases of *science for people* we find that civil society actors as well as social organizations participating. This happens for example in some identified projects whose objectives are associated with guaranteeing *food sovereignty*. The three projects identified seek to generate a space of exchange by connecting the knowledge and the practices of academia with the knowledge and experiences of the social subjects. Consequently, it mainly opens the exchange for scientific-academic communication.

One of these projects is: “Knowing the soil to promote agroecological production in family gardens”, whose objective is to analyze and contribute to improving soil management practices (such as the use of compost), and to train gardeners to improve the production of their agroecological gardens within the framework of the Urban Agriculture Program (PAU) of the city of Rosario. Likewise, there is the case of the “Taller de aguas (Water Workshop)”, which can be mentioned for the environmental sciences. It is a group formed by students, graduates, teachers and science workers, mostly from the Faculty of Exact and Natural Sciences of the University of Buenos Aires. They work on issues associated with water in socially and environmentally neglected places. They are organized horizontally and through consensus, building knowledge together with organizations working for social change.

With reference to *network science* we identify only four cases, one of computer science and three of the exact and natural sciences. They use Web tools to increase collaboration in the production of scientific knowledge and seek to encourage exchange, mainly between scientists but also with other actors. This is the case for the “Uqbar Project” that seeks to unite the industry with the academic by generating a space that promotes the use of free software for academic and productive purposes. Teachers and developers from different national universities founded the project with the objective of bringing academic research associated with software together with industrial developments in order to facilitate the learning from these resources. Another project is the Pampa2 Project (Argentinean Project for Monitoring and Prospecting Aquatic Environments) that integrates a multidisciplinary network of research teams belonging to different scientific institutions that investigate different characteristics of the thirteen lagoons in the Pampa region in order to evaluate biological patterns associated with the human activity and climate change.

Ultimately, in the practice of *open access to scientific production* national repositories have had a large role to play. A wide diversity of knowledge fields are well represented in a variety or repositories. These have profited from the Law 26.899 of Open Digital Repositories, enacted in 2013. Publications and data are opened to the *community*. Its objective is not the dissemination of science but the liberate access to scientific results generated by the researchers of the national scientific system.

There are also other open access cases such as the NOVA project — New Argentinean Virtual Observatory — which, created in 2009, collects and centralizes already processed astronomical data in order to integrate them into international standards, allowing its reuse. It gathers data in the form of images, spectra, catalogs, lists, or measurement tables, promoting efficiency and productivity in the access to, the management as well as in analysis of astronomical observations. In the very same way, the above-mentioned case of Pampa2 stands out. This project makes automatic data available, which is produced in real time by the buoys installed in some of the lagoons (and which can be accessed by anyone). It also enables access by prior request to historical data series.

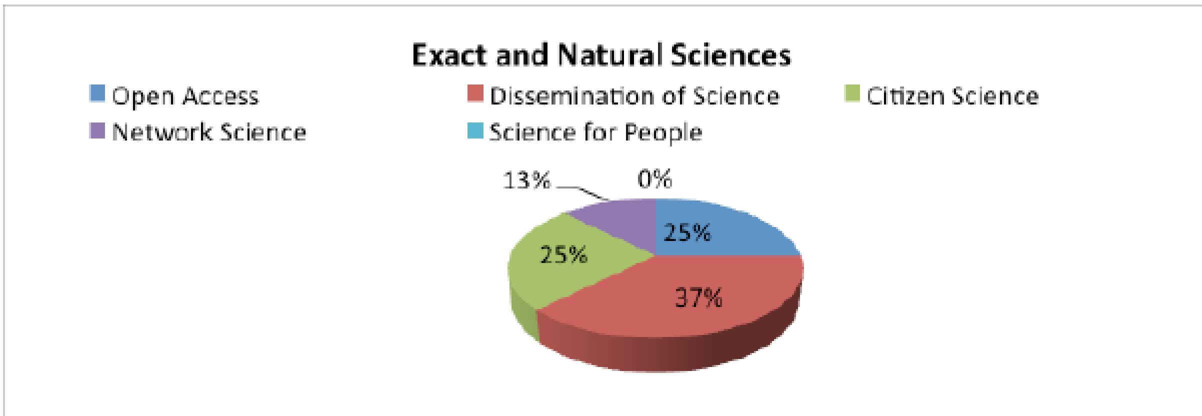

Figure 3: Exact and natural sciences experiences by type of practice.

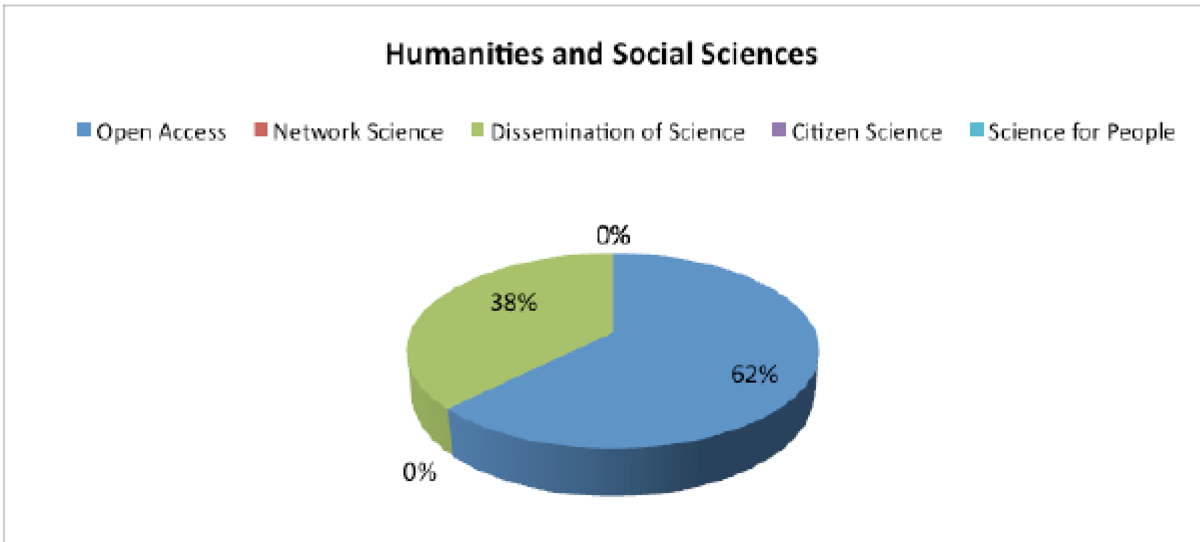

Figure 4: Humanities and social sciences experiences by types of practice.

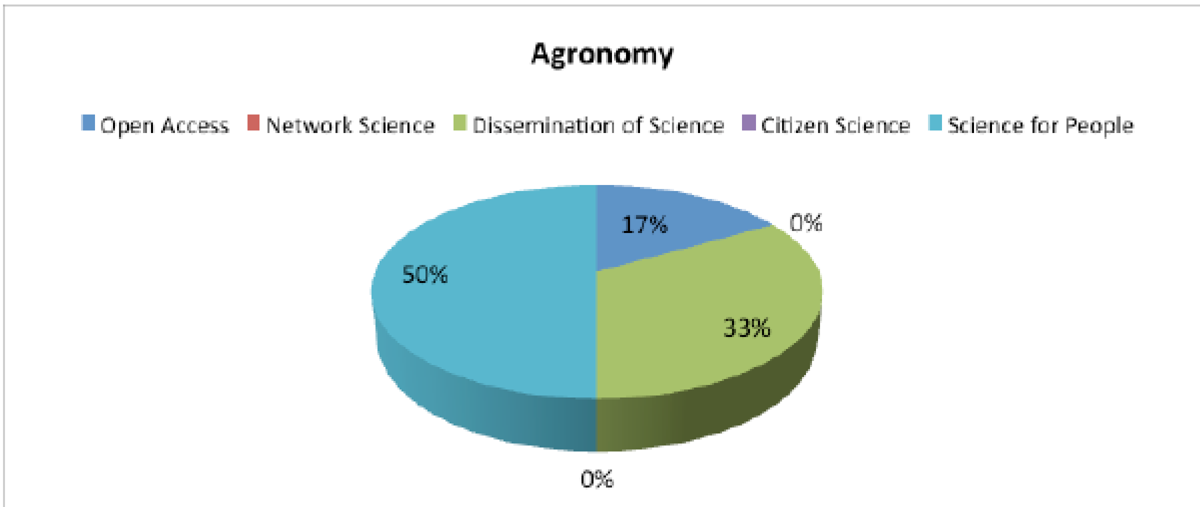

Figure 5: Agronomy experiences by types of practice.

Finally, analyzing the fields of research with more cases, we see that on the one hand, in the *humanities and social sciences*, there seems to be no great diversity of open science practices, as they concentrate mainly on *open access* to and the *dissemination of science*. Whereas in the *exact and natural sciences*, we find that there is a diversity of open science practices: including open access, dissemination of science, citizen science and network science. Last but not least, in agronomy the practice of *science for people* stands out.

5. Conclusions and policy implications

Argentina is a leader of the region in terms of public policies fostering openness and collaboration practices with the regulation of the Argentinean Law of Open Digital Repositories from 2013. This law served as an accolade for work already carried out by the libraries of various scientific institutions that are spreading the results of scientific research more openly. In addition, public policy in science and technology has been promoting the common use of instruments purchased by public funds and encouraging collaborative research projects among various actors such as scientists, companies and civil society.

However, there is still a long way to go in order to take full advantage of the benefits of openness and collaboration in science. There are some stages in the production of scientific knowledge that remain virtually closed to actors outside of respective research teams. For example, collaboration with citizens in the stage of data collection is rare in Argentina and there are few examples of citizen science. The same holds for the use of ICTs to produce knowledge among scientists from different disciplines or laboratories (networked science); or for the co-construction of instruments between scientists and other users of knowledge; or for open peer evaluation.

A policy of open science in Argentina needs to take into account the development of new tools and incentive schemes encouraging collaboration at all stages of the production of scientific knowledge. This path is likely to be initiated by designing communication strategies that disseminate the benefits of openness and collaboration in science for producing a critical mass leading to the promotion of more open and collaborative practices. As demonstrated in this paper, open science practices, their benefits and implications are not well known by local scientific communities.

The communication of the benefits of open science could be done through collaborative practices that generate new skills by training others to replicate collaborative processes, thus making results viral. For example, discussion forums should encourage the participation of scientists, policy-makers, communities specializing in practices of open source as well as the general public. New vehicles for open science could include open-ended interdisciplinary science journals; workshops for learning open science tools and practices; science hackathons open to the general public; and hybrid spaces, such as makerspaces or fab labs, that link scientists with non-scientific experts, such as hackers, electronics experts and artists.

We have also seen in this work that although open science practices are not widely known in Argentina, there is a growing range of experiences with open science. There are scientists who are interested in open science who could start experimenting with these open concepts even though they do not yet have institutional capacity or support to do so. This drawback is accentuated by those stages of research not covered by open science policies. In order to solve this problem, it is necessary to advance open science in at least three ways. First, it is necessary to recognize existing cases and experiences of open science in Argentina and in the region and, from their analysis, develop guides for good practices and policy recommendations. Second, it is necessary to build instruments that encourage experimentation with open science practices. This includes the development of online collaboration platforms between scientists; data release protocols; mechanisms that facilitate the compatibility of data between different disciplines; licenses that allow open collaboration in software and instrumental construction; and the development of new dissemination tools encouraging interaction with the public, such as online games, data measurement kits and scientific blogging platforms. Lastly, it is worthwhile to train scientists in the use of these tools and to facilitate the construction of interdisciplinary teams that include experts in communication, group facilitation and database management, among others.

Finally, the current incentive scheme for a researcher represents an obstacle for transforming scientific production into more open and collaborative forms. This incentive system relies heavily on the use of bibliometric indicators, such as the number of articles published during a given period. As we pointed out, this prioritizes competition over collaboration, and scientism and disciplinary fragmentation over the possibility that we can all use and create knowledge in a collaborative way.

To bring science closer to society, it is necessary to open science. Different tools are needed promoting the publication in open access journals; positively evaluating peer collaboration; valuing communication and intervention activities of science in society; and of society in science (*e.g.*, rewarding the effort to involve social actors in the definition of agendas); and, generally, ensuring that any evaluation system uses diverse, transparent and open criteria [10]. The decisions made with regard to evaluating the performance and progress of a researcher's career condition the research agenda (Bianco, *et al.*, 2016). Therefore, it is fundamental to think of evaluation schemes that, besides adhering to internal criteria of excellence, have an effect on the social, cultural, productive and environmental reality of each specific context.

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Notes

1. Participatory action research allows communities and scientists to collaborate in the definition of problems and methodologies for research and intervention; see Fals Borda (1979) and Freire (1982).

2. Science shops are facilities, usually parts of a universities, that provide space and support for civic actors to explore problems and propose research problems using participatory techniques (Wachelder, 2003).

3. For example, the Royal Society (Boulton, *et al.*, 2012), RIN/NESTA (2010), OECD (2015), World Bank (2012) and European Union (European Commission. Commission High Level Expert Group on the European Open Science Cloud, 2016) have expressed interest in and support for open science practices.

4. http://repositorios.mincyt.gob.ar/pdfs/Law_26899_Digital_Repositories_scientific_data_Argentina.pdf, accessed 20 June 2017.

5. See V. Arza, M. Fressoli and E. López, 2016. "Open science in Argentina: A map of current experiences," currently in review for *Revista Científica*.

6. Frequently attributed to Isaac Newton; see https://en.wikipedia.org/wiki/Standing_on_the_shoulders_of_giants, accessed 20 June 2017.

7. There are a number of examples of citizen science. For example, in 1842, U.S. Navy officer Matthew Fontaine Maury (1806–1873) found a method for analyzing meteorological information collected every 15 minutes by seafarers sailing at different points in seas and oceans. This information greatly improved weather knowledge and facilitated navigation (Cooper, 2012a; Cooper, 2012b; Miller-Rushing, 2012).

8. Dissemination of science is based on the use of different tools, forms of communication and skills to produce different responses from the public to available scientific knowledge (including interest, commitment, public understanding) (Burns, *et al.*, 2003). There are a multiplicity of approaches to the dissemination of science that coexist (Bauer, 2009). Traditionally, the dissemination of science covered a series of practices centered on the literacy of science and the provision of information to close the 'deficit' of scientific knowledge. In the mid-1980s, public understanding of science emerged, seeking to raise the level of scientific knowledge in the public to reverse the growing mistrust of scientific expertise. More recently, new outreach trends have emerged, based on the use of interactive techniques (games, videos, experiments) to encourage learning during practice rather than passive information consumption (Franco-Avellaneda, 2013). According to Wiggins and Crowston (2011), several open-network science and citizen science projects can be considered as educational projects that provide formal and informal learning services. In practice, these different conceptions of disclosure co-exist and, therefore, in some outreach initiatives the public has a more active role than in others. These are those that could be considered as part of the set of open science practices.

9. In this group, repositories not specialized in any specific discipline are of central importance.

10. See, for example, the Leiden Manifesto for Research Metrics, at http://www.leidenmanifesto.org.

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