Expanding Perspectives on Open Science: Communities, Cultures and Diversity in Concepts and Practices
L. Chan and F. Loizides (Eds.)

doi:10.3233/978-1-61499-769-6-153

Benefits of Open Science: An Analytical Framework Illustrated with Case Study Evidence from Argentina

Valeria ARZA[a,1] and Mariano FRESSOLI[a]
[a] *CENIT/ UNTREF/ CONICET*

Abstract. Doing open science is to collaborate with others in a scientific endeavor and to share the outcomes of the scientific process. However, there are many dimensions of openness. Thus when analyzing concrete open science initiatives one finds a full lot of hybrid forms of openness. We identify and discuss different elements of open science and their benefits, under the contention that benefits are related to how openness is achieved. We propose a bi-dimensional framework to characterize openness along research stages, which allows anticipating expected benefits. The first dimension accounts for the characteristics of the collaboration, while the second for aspects of access to shared outputs. We illustrate our framework by discussing four Argentinean open science initiatives.

Keywords. open science, Argentina, analytical framework, benefits, case-study

1. Introduction

In modern scientific tradition, collaboration among scientists and the production of scientific public goods have been the engine for scientific production and the justification for public investment in science [1]. Scientists have been expected to collaborate across disciplines and over generations so as to contribute to a stock of interconnected knowledge needed for scientific advance. This knowledge would be publicly shared and disseminated through publications [2]. However, in practice, scientific knowledge production has been much more closed, fragmented and isolated from social problems than the idealist conception of modern science expected, as a result of three phenomena:

Firstly, scientific practice has become locked in the pursuit of personal/individual success. Scientists compete to reach priority and much of their knowledge is not transmitted. This is due to fear of competition, criticism, convention in a given field or the intrinsic characteristics of the tacit knowledge involved. Thus, although scientists publish their results, some of the relevant information to be able to construct knowledge cumulatively is not published [3]. Notoriously, negative results of experiments are not generally published. As a result, scientific production has been much less collaborative than it could have been and also less transparent. Resources become misused affecting negatively research productivity and reproducibility (and therefore reliability).

1 Corresponding author email address: varza@fund-cenit.org.ar

Secondly, assessment schemes have been increasingly influenced by marketing strategies of academic publishers, which push for the use of quantitative indicators based on citations as proxy for research quality. Thus, researchers worldwide are motivated to guide their research to areas, topics and methods that would be widely cited worldwide [4], which does not need to coincide with societal needs [5].

Thirdly, scientific policies oriented to the commercialization of scientific knowledge have increasingly locked up scientific knowledge. Political pressures in the developed world have urged scientific production to demonstrate its social and economic utility [6][7]. In turn, intellectual property mechanisms implied the protection of scientific knowledge that previously remained in the public domain [8][9], so as to motivate private sector to invest in scientific production. These practices accelerated the processes of occlusion of science; knowledge become protected and could only be used with the owner authorization, with two different effects. Firstly, scientific incentives drove scientific production away from the idea that knowledge is a public good. Secondly, the virtue of learning collaboratively and the collective creation of cumulative knowledge stocks as platforms for future knowledge production became seriously endangered, affecting the rate of invention.

In parallel to these developments, the emergence and wide diffusion of ICTs 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 and exception.

These new opportunities extended the boundaries of what is feasible to share and how to do it, enlarging the potential scale and scope of collaboration and openness in science [3] [10]. For example, other resources besides publication can now be shared; such as data, lab notes, infrastructure, etc. ICTs also broadened the range of actors and expanded the possible time for collaboration; the contributions can be brief and there are tools to improve accessibility to facilitate the collaboration of actors with different backgrounds. Similarly, ICTs also broadened the range of actors and extended the possible time of collaboration, and the contributions can be brief and there are tools that facilitate the collaboration of actors with different capacities and expertise. In addition, new technologies such as big data, machine learning, massive use of sensors, drones and greater availability of low-cost scientific tools are changing the way knowledge is produced.

The experience of open source software created an important precedent for the open science movements in terms of know-how and visions. Open software become a community of practice where open access to knowledge and wider collaboration overcome the old prejudices that only competition allocates resources efficiently. Open source software demonstrated for several years now that massive and open collaboration works, and that it could even become mainstream practice in fields where information is a key input [11]. In fact, current open-minded movement, in science and other fields, is inspired by free software and open source activists.[2] They probed that sharing sums up.

[2] Efforts to apply open source ideas to science can be traced back to the late 90s and early 2000s. These include several declarations in favor of open access including the Budapest, Bethesda and Berlin declarations. The role of new creative commons licenses was also important in order to allow scientist to manage their publications. Finally, there were direct efforts from people closed to Creative Commons to create initiatives around scientific commons [14].

Open science is rapidly changing how science is being produced and used. However, as with other buzzwords and fashion terms, there is no single definition of open science. There are different understandings, motivations and potential benefits from open science [12] [13].

However, they all aim at (i) producing public goods: publications, data, infrastructure, and tools available to all; (ii) encouraging greater collaboration among scientists from different disciplines and academic fields; and (iii) broadening the diversity of science-producing actors. By these means, efficiency in scientific production is enhanced, scientific knowledge is democratized and science becomes better connected with societal needs. These potential benefits work as motivational goals for the different meanings and practices of open science. However, there is yet little understanding on mechanisms and conditions that link open science practices with potential benefits. There is no guarantee that opening up some scientific practices or outputs in some way would univocally trigger knowledge democratization, research efficiency, and social responsiveness.

This paper aims at disentangle different meanings for open science and organize them so as to relate them with claims on benefits as referred in the literature. We argue that the wide array of open science practices could be displayed in a two dimensional space, with one dimension being features of collaboration in processes and the other being the characteristics of access to outcomes. The specific location in this space anticipates different types of expected benefits. Our contention is that this analytical framework could be used as a toolbox to assess different experiences of open science around the world against their proposed goals.

Next section describes benefits as informed by the literature. Section 3 presents the conceptual framework that relates dimensions of openness and benefits. The methodology to empirically illuminate the framework is explained in Section 4. Section 5 describes the cases and Section 6 uses them to illustrate our conceptual framework. Section 7 concludes.

2. Benefits Association with Open Science as Claimed by the Literature

Different strands of the scatter literature analyzing open science practices claim they trigger several benefits, which we organized in three groups:

i. Improving scientific efficiency

One of strong argument for supporting open science practices is that they increase efficiency [15].[3] This is the result two mechanisms: a) wider availability of knowledge resources that makes research cheaper and research success more likely and b) more fluent collaboration among heterogeneous knowledge actors that amplifies collective intelligence and creativity.

[3] To increase efficiency in scientific production means to be able to achieve more or better scientific outputs (i.e. findings, publications, trained scientists) using the same amount of scientific inputs (i.e. resources). This relates to costs advantages or to learning advantages of openness and collaboration. In turn, we may refer also to dynamic efficiency when there is an increase in the likelihood of improving efficiency in the future given current state of the art.

Open access to scientific final or intermediate outcomes, increases the pool of knowledge in common use. This increases efficiency because unnecessary duplication can be more easily avoided and because researchers can explore new questions and solutions to problems by standing on the shoulders of a *taller* giant. Sharing promotes beneficial spillovers among research programs and makes the most of investment in science. [16] Moreover, open access also increases efficiency because it enables the use of computing power machine that interconnecting everything that is already known, reusing online available data to arrive to new findings. This new capacity has been sometimes name as *data driven intelligence* [15], and depends on open access to use automated tools to mine the literature. In turn, open data allows reproducibility of key research findings (and also experimental methods) that could push science ahead [17].

However, it is not just availability of publication and data that helps. Digital tools have also opened up opportunities for a greater quantity of actors from a wider community, not just professional scientists, to participate directly in scientific production overcoming restrictions imposed by physical and cognitive distance [18]. Sometimes they participate in data collection (see Galaxy Zoo, Foldit and Great Sunflower Project) proving the scientific endeavor with new cognitive and manpower resources [3] [15].

In turn, collaboration and interaction with the community improves efficiency also by boosting creativity. Open science practices sometimes involve communities participating in analytical or design research stages (not just data collection). In those cases, non-academic actors or scientists from different disciplines could contribute by drawing knowledge resources and cognitive tools from their own experience, which throw new light to research problems. Social studies of science claimed that major innovation in different fields tend to be put forward by scientists trained in different disciplines, mainly because they are not bound by professional traditions [19] . A similar phenomenon has been observed in studies about innovation [20]. Jeppensen and Lakhani (2010) [21] claim that it is not just technical marginality but also social-political marginality which may contribute with novel ideas, for similar reasons, these actors are more prone to thinking unconventionally and therefore more creative.[4] Wider participation and interaction among diverse set of actors enable the mechanism known as 'the wisdom of the crowds' [15] [22], which basically states that a group could better solve a problem than any single individual from the same group.

Finally, collaboration among scientists in the same field triggers a different mechanism to improve efficiency. When they are able to interact fluently, collective intelligence is amplified by the mere fact of being able to share, validate and quickly rule out different ideas, assumptions, hypotheses or avenues of inquiry [15].[5] This consequence of collaboration is greater when using web technologies because it gets across once unconceivable distances of time and space and ideas could quickly go back and forward feeding from the interaction, augmenting the capacity to solve problems (see, for example, the Polymath project).

ii. Improving democratization of scientific knowledge

---

4 However, greater collaboration with non-scientific actors will probably require a lot of boundary work to translate scientific information to a wider public (see [23]).

5 Nielsen, 2012 [15] argues that such amplification of collective intelligence probably works better when interactive actors share at least some cultures of practice or when they are focused on the same problem-solving strategy.

There are three complementary mechanisms through which open science practices democratize scientific knowledge: by improving access to scientific resources; by enabling the participation of a wider community in the research process; and by making science better understandable for a wider population.

Open access movements emerged as a reaction to the closure of scientific knowledge imposed behind paywall to access scientific publications. While the rate of scientific production has been always increasing, the distribution in the possibility of using such knowledge has remained unequal [24]. Aronson (2004) [25] estimated that 56% of institutions in lowest income countries have no subscriptions to international journals in medical research. Open access is potentially democratising because it reduces the costs of using and reusing the worldwide accumulation of knowledge.

Open access increases the pool of information available to anyone not just scientists. Nurses, patients, teachers, students may get to interested to learn about latest treatment of certain diseases; small businesses may get to know about relevant techniques in several application fields; etc. A recent survey to Latin American users of open access portals show that 25,2% of articles were downloaded for non-academic use; either to satisfy personal interests (10.5%) or for professional practice unrelated to scientific production (non for profit: 4.2%, private: 3.8%, public 6.7%) [6] [26].

The same could happen with open data; when properly curated and easily available, it could be used by different actors including scientist from different disciplines but also the non-scientific actors such as NGOs, firms, and just citizens (see for instance [27]).

Scientific publications and data are an outcome of research which is largely funded with public investment (see [28] [29]). Thus, it is just fair that everyone could access to the outcome of the efforts of everyone. This idea is so powerful, that open access to data and publications as a way to improve the actual use of scientific knowledge, has become the focus of several public policies initiatives promoting open science. [7]

Open access contributes to a better informed society and fosters new processes of learning [30] [31] [32], which drives us to the second claim on open science as a democratizing force. Some open science practices promote wider participation of the society in the production of scientific knowledge. One example is citizen science projects, in which non-academic actors contribute to the production of scientific knowledge in disciplines like ornithology, astronomy and environmental conservation [33]. The emergence of new digital tools and web based protocols for gathering data is widening the scope of people that can participate of scientific research beyond "a privileged few" [34]. Furthermore, participation in the production of scientific data

---

[6] The reported data was for Scielo based on 58957 downloads. For Redalyc, based on 22910 downloads, 16% for non-academic use, split into personal interests (7.9%) and professional non for profit: 2.9%, private: 1.9%, public 3.4%),) percentages are the following:

[7] This includes, for example, the implementation of norms that commit scientists to make their publications and data freely available; changes in the form of the evaluation acknowledging and incentivizing the publication of the datasets [35] [36]; the creation of open digital repositories; the promotion of learning in management and data analysis [37]; the creation of incentives and mechanisms of acknowledging the support of the development of an open (software and tools) infrastructure [38] [36]; and the generation of new forms of publicly communicating science [37]. In Latin America Argentina and Perú are pioneer countries to get specific legislation to guarantee open access to publicly funded scientific outputs. In Argentina open access policies are institutionalized by the enactment of The National Law for the Creation of Digital, Institutional and Open Access Repositories (approved in 20137 and fully in force since 2016). After Argentina and Peru, other countries in the region started to move along similar paths.

allow learning processes leading to the construction of new questions and skills and, eventually, the development of forms of "science by the people" (see [39]). In cases such as biohackers and do-it-yourself data recollection projects, this has challenged the hierarchies and traditional orientation of science (see [40]).

However, there are still costs associating to training potential users so they become able to enjoy all functions of shared outputs and make the most of open access. These costs are inversely related to the investment in knowledge translation and communication efforts, and as Catlin-Groves (2012) [33] suggested, more complex data involvement from non-scientific actors will demand more training. This point links to the third motivation for open science projects associated to democratization: to make science understandable for a wider public [12] by fostering scientific education [18] or by designing tools and exploring new channels to disseminate scientific information (see [41]).

There is a multiplicity of approaches to the dissemination of science [42]. Traditionally, the focus was on closing the information gap regarding 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 distrust of scientific expertise. In the same vein, more recently, new outreach trends have emerged, based on the use of interactive techniques (games, videos, experiments, etc.) to encourage learning during practice rather than passive information consumption [43]. According to Wiggins and Crowston (2011) [18], several open science projects can be considered as educational projects that offer formal and informal learning services. There are also other initiatives promoting scientific education directly, such as online forums and online training courses such (tutorials, massive online courses, etc.) (see for instance [44]). Some open science initiatives are starting to introduce open science tools in students' curricula as a way to improve learning and research capabilities [45].

iii. Improving research capacity to attend societal needs

There are three mechanisms claimed by the literature on how open science practices improve the research capacity to solve societal needs.

Firstly, wider access helps visibility. Open science practices could help local problems to become visible and better communicated [36]. When using digital tools and social networks the dissemination of open access information allows that problems affecting powerless actors to become better known [31]. Marginalized groups could become better endowed with knowledge resources and political support to engage negotiation with other actors like authorities, the press or other potential supporters that could contribute to solving their problems [24].

Secondly, by promoting community actors to participate in the scientific endeavor the research agenda could be better guided towards solving problems affecting that group [37] [36]. Moreover, when the community gets involved in research, people could grab from their own informed experience to offer inputs for developing solutions, improving therefore the final outcome.

Finally, the open availability of scientific resources deters private appropriation of such resources. This could contribute to find cheaper solutions to societal problems. Open access and open licenses such as creative commons avoid the creation of barriers that hamper the process of turning scientific knowledge into concrete solutions to local problems. The societal impact of scientific research depends, in turn, on the potential for promoting a wide appropriation of research outcomes, through open access and open licenses [46]. This reacts against the phenomenon known as the "tragedy of the anti-commons", which turns out when there is such an accumulation of patents on small fractions of knowledge that makes it cumbersome and highly costly to combine all of those separate elements to produce useful solutions [47]. In contrast, open science practices are then seen as an alternative business model that could solve the anti-commons problem relying on open access, worldwide collaboration and open licenses. An interesting area where there is experimentation is open source drug discovery. These projects are creating open knowledge resources that could be freely used (e.g. Open Source Malaria [48]; Open Source Drug Discovery [49][50]; Malaria Box [51][52]; among others). Most of them, and not by chance, are oriented to produce drugs for tropical disease, where the economic rewards are low and not enough for large companies to get into business.

3. Conceptual Framework to Organize Open Science Practices

This section aims at organizing the different meanings of open science in an attempt to better relate practices with potential benefits. The intention is not to create an ideal type of open science, but rather to visualize some common aspects and, at the same time, to highlight that there are different paths to improve efficiency, democratization, and societal responsiveness of scientific practice. Open science practices have been previously classified according to: i) what is shared (e.g. publication, data tools etc.); ii) how it is shared and, iii) with whom to share [38]. We build on this classification to create a bi-dimensional framework for open science practices.

We use Benkler's twofold characterization of open and collaborative knowledge production [53][54]. A first dimension characterizes how actors **collaborate** among each other to produce knowledge, and a second one characterizes **access** to shared outcomes. Thus, while the first dimension characterizes social exchange of ideas to produce knowledge, the second one refers to existing institutions that regulate the capacity of social actors to use knowledge resources.

There are different aspects of **collaboration** that matter to achieve beneficial outcomes. We claim the *scale* of participation is important to activate mechanisms such as 'the wisdoms of the crowds', or the 'collective intelligence', or to reduce the costs of producing research as in the collection of data in citizen science practices. We also argue that not just scale matters but also the level of *interaction* among participants. Process of collective intelligence, for example, will not occur iF participants do not have the chance to rapidly rule out or validate their ideas [15]. In addition, learning is always an interactive process [55] and learning is key for democratization. Moreover, also *diversity* or a participation of a wider community in the scientific endeavor matters for the democratization of science, and for other mechanisms related to efficiency such as 'the wisdoms of crowds'. Finally, another aspect related to collaboration that matters especially for societal responsiveness but also for democratization is the degree of *participation and commitment* [56].

The second dimension aims, in turn, to take into consideration aspects of **access** to shared resources. This is related to the common based characteristics of shared resources. As in open source, the backbone principle of open science practices is that scientific resources should be used and re-used by everyone. However, there are formal and informal restrictions that make this principle work to different extent in practice.

For example, open access could be restricted by different types of paywalls (e.g. subscriptions to journals or licenses to used patented knowledge) or other formal restrictions to use, distribute, reproduce, etc. [57]. There may be also informal restrictions to use and re-use knowledge resources related to the specific skills, capabilities or capital resources needed for using shared scientific outputs.

When relating this dimension of open science with potential benefits, we could realize that some specific aspects of access matters relatively more in some cases than others. *Unrestricted open access* to publications and data matters for mechanisms affecting efficiency, such as 'data-driven efficiency'. For achieving these benefits, it would be enough to guarantee open access to academic actors. However, for democratization open access is needed also for a wider community. In turn, what really matters for democratization is to improve the *accessibility* to scientific knowledge to guarantee that a larger quantity and wider variety of actors become endowed with knowledge resources. Improving the communication of science could help in this case. Similarly, for solving societal needs accessibility is needed but what becomes crucial is to augment the *visibility* of societal needs and achievements [58]. For that aim, no just communication techniques but also a diversification of channels of communication could help.

These bi-dimensional characteristics of openness and collaboration could be drawn in a Cartesian diagram such as that in Figure 1. We also include in the Figure the different mechanisms and the associated potential benefits as have been discussed above. The actual location of benefits in the Figure is speculative. It was done by imagining that each of the different aspects of collaboration and access pulls towards the vertical or the horizontal end respectively. Thus, for efficiency, we venture that the collaboration dimension is particularly important, while both of them are important for societal responsiveness but especially for the democratization of science.

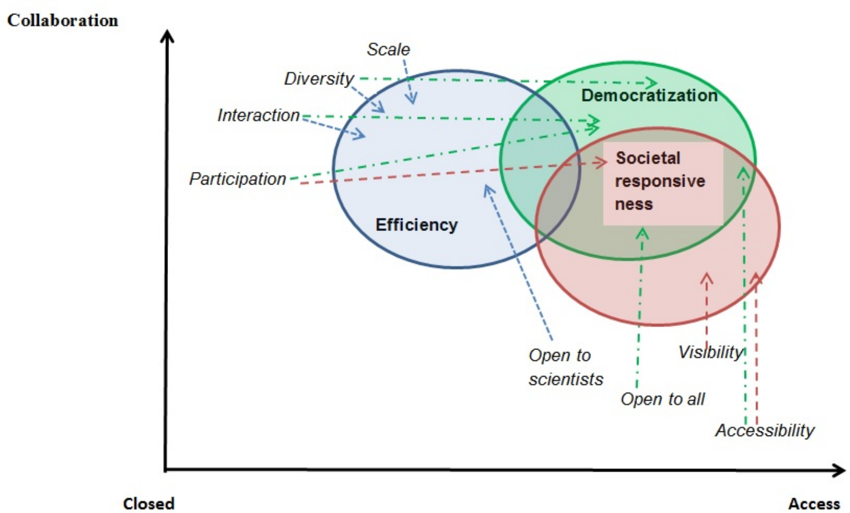


Figure 1. Two dimensions of open science

4. Analytical Methods in Case Study Research

We aim at characterizing open science initiatives in terms of the bi-dimensional framework presented in Figure 1. We will them relate location in the diagram with evidence-based benefits achieved by each experience.

Four case studies were selected from a group of open science experience identified through a national survey[8] - later enriched by online inquiries and discussions and interviews with key informants.[9] Case-study selection for this research took into account the need to cover the widest possible diversity of situations of openness processes to explore the heterogeneous spaces in which open science is being implemented in the country [59]. Among factors of heterogeneity we considered: research disciplines; socio-political contexts in which research was carried out (i.e. more or less subject to political disputes); processes of knowledge production (i.e. uni-disciplinary or transdisciplinary); techniques of participation (i.e. citizen science techniques, participatory action research, workshops, etc.); type of infrastructure (e.g. open databases; use of remote sensors, mobile applications, etc.).

The selected projects were: New Argentinean Virtual Observatory - NOVA (astronomy); Argentinean Project of Monitoring and Prospecting the Aquatic Environment - PAMPA2 (limnology); e-Bird Argentina (ornithology); and Integral Management of the Territory – IT (geography-chemistry)-.

In 2016 we carried out structured interviewed performed to one leader of each of the above-mentioned open science initiatives, to calculate the specific location of each initiative in terms of Figure 1. Closed questions were designed to assess levels of openness in a 4-points Likert scale in terms of participation, interaction, diversity of participants, access and accessibility along six different research stages: 1. Research design; 2. Collection of data; 3. Analysis; 4. Documentation and Publication; 5. Public/Social communication & engagement; and 6 Infrastructure.[10] In addition to their responses, we assess (in a 4-point Likert scale) aspects of *scale* of collaboration and *visibility* of research outcomes, based on additional data requested to interviewees (e.g. quantity of downloads, visits to their websites, followers in social networks, etc) and other secondary evidence we collected online (e.g. communication outcomes, characteristics of their website, etc.).

Case studies narratives were developed using semi-structured interviews to three referents for each project. These interviews were carried out in 2015 and they covered aspects of benefits and motivations, collaboration activities, infrastructure, financing, etc. We completed their accounts using secondary sources such as project reports, media stories and other material available primarily on the projects' website during 2016. This information is the basis for our empirical account on projects' benefits. Counterfactual information does not exist and our assessment is not based on project

---

[8] Survey was conducted in May 2015 using an online form to researcher form the Public Scientific Systems, largely those employed by the National Council for Scientific and Technical Research (CONICET) whose emails were available online 1463 researchers responded the survey. This implied a response rate of just 8%. The questionnaire was sent just once by email to every.

[9] We interviewed four key informants: one representative from the area of digital repositories of the Ministry of Science and Technology; one from a public-private organization specialized in R&D in ICTs (Fundación Sadosky); an advocate of open access; and a representative of a National University liaison office.

[10] The identification of research stages was inspired in RIN/NESTA, 2010[38], which includes seven different stages of the research cycle: Conceptualizing and networking, Proposal writing and design, Conducting and presenting, Documenting and sharing, Publishing and reporting, Engaging and translating, and Infrastructure.

impact systematic evaluation. Rather, it is partial and largely anecdotal based mostly on perceived benefits as expressed during interviews and other secondary evidence we got access to. More specifically, efficiency was assessed based on publications and citations to representatives of each of the initiatives[11] and other achievements such as participation in follow-up projects, quantity of data collected, etc. We do not have data to assess processes of collective intelligence, data driven intelligence, or amounts invested for each initiative. For democratization and social responsiveness our empirical data entirely relies on representatives' perceptions based on their comments during interviews.

5. The Four Case Studies

5.1 NOVA - New Argentinean Virtual Observatory

NOVA was launched in 2009. It aims at centralizing astronomical data and making them available to all users. It was created by researchers from various institutions in the country as a digital platform that aims to store and share already processed astronomical data. It facilitates collaboration of local and international astronomical community, through documentation, digitization and open access to data.

As a virtual observatory, NOVA has not required large investments in terms of infrastructure. The development of the site uses existing open source software developed by the Virtual German Observatory (GADO). In addition, an open software application to automatically upload and validate new pictures was developed locally. NOVA also developed digital manuals and organized training sessions for astronomers to encourage the use of the NOVA site.

The astronomical information stored in the database is open access and can be used by astronomers, researchers from other fields, students and the general public. However, it requires certain level of expertise to use specific software for image visualization.

The experience of NOVA and the aim of its founders to use it an educational tool triggered the conception of a related Project called Galaxy Conqueror. This is a game that motivates citizen to mark possible galaxies surfing on sky image as if it were Google map. It offers a brief tutorial that teaches basic characteristics of galaxies. Galaxies identified by users are then checked by volunteers from NOVA. Since the creation of the game in 2015, 50 new galaxies were identified. The game is part of a Citizen Science platform called Cientópolis, managed by some of the organisations that participate in NOVA.

5.2 PAMPA2 - Argentinean Project of Monitoring and Prospecting the Aquatic Environment

The Argentine Monitoring Project and Exploration of aquatic environments, better known as PAMPA2, started in 2011. It is an initiative that seeks to understand the reaction and behavior of water from lakes and ponds to certain natural and human

[11] We searched for publications authored by project leaders indexed in SCOPUS and we compared them annually before and after the beginning of each of the project.

events, to improve the design of management plans that may prevent deterioration and to preserve the population health.

PAMPA2 is an interdisciplinary network of scientists from seven different research laboratories. Lagoons are regarded by these scientists as early warning systems; thus, by analyzing them the project could contribute to detect changes that would eventually affect the whole region. This, in turn, could help to design technical and financially more viable resource management, mitigation or adaptation plans that take better care of the environment and the health of the population located in the nearby. To monitor the lagoons properly, diverse type of data are needed. So an interdisciplinary team of oceanographers, meteorologists, biologists, zoologists and engineers was formed to monitor thirteen lagoons distributed in the Pampa region during five years. Laboratory information from samples collected monthly or every six months from the lagoons is produced by participating teams.

In addition, in five of these lagoons buoys equipped with automatic sensors capable of measuring temperature, pressure, wind, rainfall, humidity, oxygen, chlorophyll and depth they have been installed. These devices are connected to a processor that stores information and then transmits it in real time to the laboratories responsible for its operation. Information can be openly accessed for free in a website but only for the present month, given restrictions in their infrastructure. Historical data generated by the sensors as well as other information generated by the project can be requested to the teams.

Originally, buoys were not designed following an open source approach; but the team is currently working in a new design based on open source software for more ambitious monitoring projects (i.e. buoys that can support more extreme environments, such as those in open seas).

Only those teams that originally formed the network participate in the design, collection and analytical phases. Actually, the project was designed predominantly by one of the networked organizations. There are no formal instances for interaction by all members: just one workshop held every year.

In terms of accessibility, one of the goals of the project was to disseminate results to a wider audience, especially the population living close to the lagoons. However, these activities were not performed so far because the team does not have the required expertise for doing public communication nor can they get the necessary resources to hire these services. Another shortcoming in terms of diffusion is that the website has not been designed so as to be easily used by outsiders.

Moreover, there is no written a protocol to allow users to work properly with the data the project produces. However, researchers do receive frequent requests from people that look at available data, for example for recreational or productive purposes.

PAMPA2 enabled increased interaction with other similar research projects around the world. It became integrated to the GLEON Network (Global Lake Ecological Observatory Network), an umbrella for organizations around the world that monitor lakes continuously through instrumented buoys. Similarly, some of the participants of PAMPA2 are also involved in the SAFER Project (*Sensing the Americas′ Freshwater Ecosystem Risk from Climate Change*), an initiative that integrates scientists from different disciplines from Argentina, USA, Canada, Chile, Uruguay and Colombia, in an attempt to define management and mitigation strategies which are both technically and economically feasible as well as culturally acceptable. This project includes several components to engage with civil society.

5.3 Integral Management of the Territory - IT

After the tragic floods in 2013 left the city of La Plata under water and caused nearly a hundred deaths, an interdisciplinary group of researchers designed an action-research project for integrated land management seeking to relieve the needs of two particularly affected areas. Thus, they expect to identify environmental consequences of this phenomenon to start thinking and developing appropriate technologies to help to reverse them. The project started in 2014.

The research group is formed by geographers, historians and environmental chemists. The project worked on two vulnerable areas that have been particularly affected by the flood events and it means to achieve an orderly, planned and sustainable land management. Two stages were involved: diagnosis and implementation of proposed solutions. At the time we did the case study they were half way through the first stage.

The neighbors participated in two ways during the first stage: in the so-called Catalyse method, by collectively designing the survey so that their views and needs were included from the beginning in the questionnaire, and in the sampling of rainwater, which measure their level Ph (to detect the acidity or alkalinity of water). These samples were then delivered to investigators.

The analysis of all collected data was performed by researchers (without the participation of the neighbors). And the obtained data have not been made public yet.

5.4 e-Bird Argentina

eBird is a citizen science project that receives bird sightings from anybody in any part of the world. The online platform was developed in the United States in 2002 by the Ornithology Laboratory at Cornell University and the National Audubon Society. In Argentina the portal started in 2013.

The platform is open access and it aims at managing and sharing online data of bird sightings made by amateur and professional watchers. eBird makes use of free software tools and online collaboration to efficiently gather, archive, and distribute information about birds to a much wider audience. eBird's regional portals are customizable in response to the need to meet the demands of local users. Each portal is integrated into the application infrastructure, and the whole database is saved in servers located in the United States.

The large amount of data collected by eBird, which contribute information about the spatial distribution of species and allow population trends to be followed, can help in the identification of important areas and sites for the conservation of birds and contribute, in this way, to the design of better plans for managing or recovering threatened species or those in danger of extinction.

Bird watchers who use eBird to report their sightings must follow a standardised protocol to load the information to guarantee the uniformity and quality of the registers. This protocol is quite dynamic and has improved with time, successively adding different characteristics that allow the watchers' data to be classified in a more precise way. Automatic control filters detect "unusual" registers. These are resent, also automatically, to the user who created them to check the data that has been flagged. If the data is confirmed to be correct, the list will then be passed to a regional expert, called an "inspector", for evaluation. If the register is rejected it will not form part of the eBird database, although it will be saved in the user's personal register. Interaction with the watchers is crucial for improving the quality of the controls, especially in regions where there is only one inspector for a very extensive area. In Argentina there are currently 20 experts who work as inspectors on a voluntary basis. Beyond the voluntary work of experts, other personnel dedicated locally to the project is minimal (four people), and as such it is entirely a citizen science project, depending on the voluntary participation of an amateur public.

The site appeals to amateur bird watchers who traditionally made their own lists of birds. One of the attractions of eBird for them is the ability to track their personal bird listings, share their data with other users, receive alerts about rare birds, upload their old sightings lists, explore information about when and where to find birds (which could be useful, for example, in planning a field trip), and play games that appeal to the competitive spirit. The site also gives users recognition for their sightings.

6. Openness and Benefits in a Bi-Dimensional Space

Table 1 assesses the different aspects of collaboration and access using information from the case-studies. This information is used in Table 2 to build indicators of expected benefits by calculating mean values on relevant aspects for each benefit as depicted in Figure 1. Figure 2 plot values from Table 2.

The four initiatives are heterogeneous in terms of dimensions of openness. Some aim at increasing collaboration while others are mostly based on improving access, accessibility and visibility of scientific outcomes. As a result, potential benefits also differ. Our goal in this section is to contrast expected benefits with actual empirical data on efficiency, democratization and social responsiveness.

Table 1. Degree of openness in different dimensions along the research cycle, 1-4 Likert Scale

		IT	**Pampa2**	**Nova**	**e-Bird**
i	Scale	1,6	1,6	2,0	3,7
ii	Diversity	2,8	2,4	1,3	3,3
iii	Interaction	2,0	2,8	2,0	2,5
iv	Participation	3,2	2,0	2,3	2,7
v	Visibility	2,0	1,0	2,0	2,5
vi	Accessibility	2,0	3,0	2,5	3,0
vii	Access by scientists	2,0	2,5	4,0	4,0
viii	Access by everyone	1,5	2,5	3,5	4,0

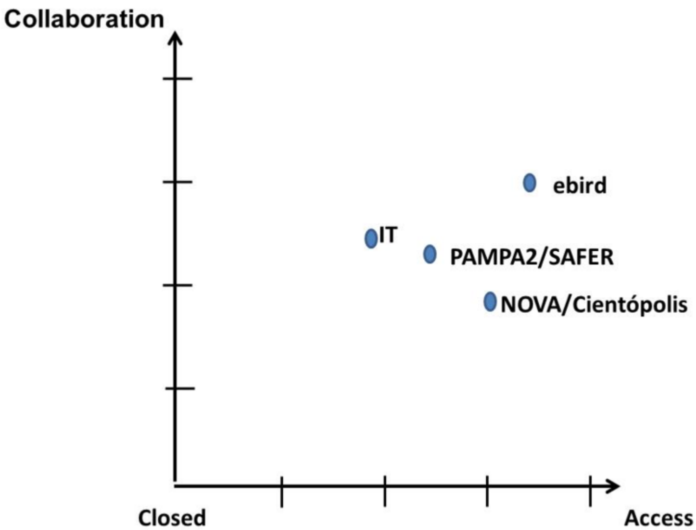
Source: Own elaboration based on responses to structured and semi-structured interviews (rows i, ii, iii, iv, vi, vii and viii) and completed with secondary information (rows i and v)

Table 2: Indicators built as mean values of different dimensions from Table 1 as informed by Figure 1

Indicators					
		IT	**Pampa2**	**Nova**	**e-Bird**
i to iv	**Collaboration**	2,40	2,19	1,92	3,04
v to viii	**Access**	1,88	2,25	3,00	3,38
i+ii+iii+vii	**Potential Efficiency**	2,10	2,31	2,33	3,38
ii+iii+iv+vi+viii	**Potential Democratization**	2,30	2,53	2,33	3,10
iv+v+viii	**Potential Responsiveness**	2,40	2,00	2,28	2,72

Source: Own elaboration based on Table 1

Figure 2. Four open science initiatives located in the two-dimension space of open science



Source: Own elaboration based on Table 2

eBird is the case that ranks the highest in most dimensions as can be seen in Table 1, which drives to high levels of expected efficiency, democratization and social responsiveness in Table 2.

In fact, the platform allowed the generation of a large database, updated daily, which can be used for the identification of areas that are critical for conservation of birds.[12] Since 2013, approximately 95% of bird's species in Argentina have been detected. Moreover, the platform enabled the interaction among professionals and

[12] In 2016 eBird international informed that more than 1/3 million eBirders have submitted 370 million bird sightings, representing 10,313 species (see http://ebird.org/content/ebird/news/2016review/ , Accessed 16th January, 2017)

birdwatchers around the country that improved the quantity and quality of stock of shared resources. This has been highlighted by representatives of e-Bird Argentina:

> "It is likely that without the volunteer work of birdwatchers and the collection infrastructure, it would not have been possible to gather this gigantic amount of data, globally"
>
> "Interaction with birdwatchers is crucial for improving the quality of controls, as experts can act as guides for inexperienced observers to improve their observational skills and to incorporate good data quality into the system."

Moreover, publications by Argentinean eBird representatives have doubled since the beginning of the project, while the annual citations to their work have more than tripled. We do not have data on the extent to which data from eBird Argentina were actually used in scientific projects, but there is anecdotal evidence that this was the case for the e-Bird international [27]. In fact, Argentinean representatives particularly value the potential use of their data for science and policy purposes.

> "For us, the project usefulness are the data. […]. These maps [of distribution of the species] have changed completely… for example, by overlapping a map of the distribution of the species made in 1975, the eBird data show which species expand their distribution or which have reduced or no longer exists."

Something similar can be said about the potential for democratization and social responsiveness. The project ranks the highest for those indicators in Table 2 because data is open access; the platform is very user-friendly, they advertise vastly their initiative (party relying on international efforts in this regard) and the infrastructure is open source.

In fact, there is evidence that the initiative had some effect on capability building. eBird familiarizes participants with the use of standardised techniques of data collection, sometimes using national contests. It increases their knowledge about birds, habitat, ecology, etc. through the interactive visualization tools, and it improves their ability to watch through interaction with regional experts. In sum, it leads to building amateur bird watchers' expertise.

Although, eBird stands out in all expected benefits and there is evidence that in fact this initiative showed great achievements, our conceptual framework is more useful to identify benefits within specific experiences than to compare outcomes across them. Every initiative may have very different goals, history, resources, etc. for comparability to make sense.

Under this light, we may say that eBird stands out in efficiency, NOVA in efficiency and democratization, PAMPA2 in democratization and IT in social responsiveness. Let's analyse whether the evidence accompanies these expected benefits.

NOVA has been very beneficial in terms of data sharing and data re-use among astronomers. The project has done a great effort to take astronomic data and images out from individual computers and to share them openly with everyone. This was recognized by the project representatives:

> "The most relevant, I think, was the VVV Survey because we uploaded 400 million positions in space with astronomical data and it was a challenge, in terms of data magnitude and the idea is that they continue to upload a lot more."

This has improved the quantity of information that is available for common use. Since the initiative started in 2009, there has been 125.075 data downloads. In 2016 there were 4171 downloads per month and in total 9400 monthly visits to the data repository. As in the case of eBird, the project leader has dramatically increased the number of annual publications and their annual citations (128% and 332% increase, respectively).

This information then agrees with efficiency as being one on the main expected benefits of this initiative. The other important expected benefit in Table 2 is democratization. Although our evidence suggests that NOVA ran a bit short in terms of amplifying its impact beyond the scientific community (e.g. their platform is not very accessible for the wide public), this has been changing lately with the creation of sister project which uses citizen science practices (Galaxy conqueror). This has improved the diffusion of astronomy among the wide public, and it might also contribute to capacity building and democratization of science, as has been observed in similar cases such as Galaxy Zoo.

> "People play but they do not forget they are in the real world with a certain purpose and, that makes it more fun" Galaxy Conqueror programmer."

Something similar happens with PAMPA2. Expected benefits (Table 2) seem to be primarily related to democratization. Evidence suggests that this is very much related to its international spin off project (SAFER), which is trend-setting in the use of community based strategies to produce knowledge and to manage natural resources. The diffusion of results to a wider audience is contemplated among the goals outlined by SAFER. For instance, this implies plans to spread the results of the project among the populations in the vicinity of the lagoons.

Not all participants of PAMPA2 participate in SAFER. Evidence based on PAMPA2 exclusively pushes us to conclude that they could do much better in terms of democratization. PAMPA2 project lacks a friendly website. The one they have, where they share buoys data, is not designed to receive inquiries from the public. Yet, researchers receive regular inquiries from people who consult the data available, such as for recreational and/or for productive purposes. As the process of opening of PAMPA2 advances, new challenges arose in diffusion of data, which in turn require better infrastructure and some precautions around the use of this data.

> "People who know that it exists and that is getting access to data that has not existed before… To those the project has helped… they could find the data useful. The only weather station from Monte Hermoso, or Pehuen-có is our station, so they enter our station to know what data are available. (..) But we also have to be cautious: it is something that we do and we release freely available but these are research stations, they are not official stations of weather forecast established by an authorized body."-PAMPA2 and SAFER Representative

PAMPA2 does seem to be doing quite well in terms of scientific performance. The group managed to create an interdisciplinary network of scientists who collaborate locally and internationally. Actually, open access to data has opened up opportunities to participate in new international projects widening local scientists' networks. The evolution of annual publications and citations has increased in 218% and 144% respectively since the beginning of the project. As a matter of fact, our interviews referred directly to the possibility of improving publications as one of the benefits they associated to the project.

> "We have already produced a special issue in a good quality high impact indexed Journal. It has data produced by our project and also previous data of the region."

> "We have co-authored several articles (…) good outcomes came out from our network and workshops, etc. We've presented our data in many congresses, seminars, conferences."

Finally, although the topic being investigated is central for communities, social responsiveness does not seem to be one of the promises of PAMPA2 (Table 2). It does not experiment with citizen science tools for data collection and it does not have a community capability building component. SAFER does, and so we could expect social responsiveness to improve as the new project develops. SAFER has an educational component and works with students from a middle school. Students collect data with the help of the IADO research team, and perform measurements of pH, water temperature, turbidity and they also take pictures. In 2014, this information was used in the school science fair. At the time of the interviews, the research team was putting together a basic kit with measuring instruments to perform periodic monitoring and if the experience were successfully concluded, they pretended to extend it to other areas.

In turn, the main expected benefit for IT is social responsiveness. The project was an ongoing project at the time of our case study, so we cannot really assess its benefits. The local community that participated in the project has increased their knowledge about territorial planning and they have also collected some data that could back their claims in the future. Thus, it does seem to be some evidence that the project is oriented towards achieving this expected benefit.

> "We propose a work methodology that brings people closer to the University. … to return the value back to people ... we, as scientists, get closer to the communities so that policy could be designed using more elements of judgment, from science, knowledge and with social support."-IT Representative

> "Then, when we go back to neighborhoods with the processed information … people become aware of what they had built … it contributes to a better knowledge balance."-IT Representative

Democratization also ranks high in Table 2, but in this case our evidence suggests that this achievement was somehow hindered by the political context in which the project emerged. Researchers said that it was puzzling to work with local communities in the context of political disputes (with local authorities), because they (the researchers) did not want to create false expectations on the outcomes of the project, while at the same time they needed to motivate the community to be part and committed to it. One specific and important problem faced by the project at the time of the interviews was political barriers to enable open access to data. Local authorities retained the right to decide when it was a reasonable (political) time to show certain results and to define what and when solutions would be carried out. They said:

> "It is not that data will not be known by people, on the contrary. But there should be some kind of mediation, so that it does not generate tensions, because data are very sensitive. The idea, of course, is always to democratize all the information that emerges from the investigation ... at different time stages, and with the needed care, so that instead of generating tensions, it could generate agreements. An untidy diffusion, generates the opposite one wants to ... that is, to get positions closer to each other."

Efficiency, in turn, does not seem to be one of the main promises in terms of how the imitative was designed and in fact, our interviews showed multidisciplinarity somehow risked the likelihood of obtaining publishable outcomes, partly because specialized journals normally belonged to certain disciplines and also because the final outcomes depended on the commitment of other researchers in a context where quality could not be cross-checked due to lack of specific skills. Annual publications and citations have increased annually since 2013, but much more moderately in comparison to the other mentioned initiatives (56% and 33%).

In sum, our conceptual framework helped us to identify the main expected benefits of each initiative which were largely validated by evidence we collected for each of the case studies: e-Bird stand out in all outcomes, but specially efficiency; NOVA in efficiency and democratization (thanks to its spin-off project), PAMPA in Democratization (thanks to its spin-off project) and efficiency and IT in social responsiveness.

7. Conclusions

This paper organizes different elements of openness in order to relate them to specific benefits claimed by the open science literature. We argue that benefits are related to the specific characteristics of the opening process. We built an analytical framework based on eight aspects (Scale, Diversity, Interaction, Participation, Visibility, Accessibility, Access by scientists and Access by everyone) of two key dimensions of open science: collaboration and access.

Using data from four case studies of open science initiatives from Argentina, we related the specific features of openness and collaboration with three reported benefits of open science as discussed in the literature: efficiency, democratization and social responsiveness. Our point is that there are several directions of openness and they could lead to different types of benefits.

The implications of these finding are that there is no need to commit to total openness to enjoy benefits of open science. There is no one single pathway to opening up; there are diverse dimensions scientists could explore, depending on their goals. Actually, in line with Whyte and Pryor (2011) [60] our findings show that researchers do not normally commit to total openness but rather attempt to open-up pragmatically, responding to specific requirements by funders or taking advantage of specific opportunities. Interestingly in our cases, once scientists start opening up some part of the research project, they later usually become interested in further the opening up other dimensions and stages of the research process, sometimes through spin-offs projects.

We believe our analytical framework could be informative for researchers, policy makers and practitioners as a guide for characterizing open science experiences and also, helping to identify specific aspects of open science practices that could be opened-up further for specific targeted outcomes.

Acknowledgements

The funding for this work has been provided through the Open & Collaborative Science in Development Network (OCSDNet) research project, supported by Canada's International Development Research Centre and the UK Government's Department for International Development. Find out more at www.ocsdnet.org and by the Interdisciplinary Centre for Studies on Science, Technology and Innovation (CIECTI) from the Ministry of Science, Technology and Productive Innovation of Argentina. In addition we would like to thank all our interviewees for their time and ideas shared with us in several opportunities.

References

[1] David, P. A., 2009. Towards a Cyberinfrastructure for Enhanced Scientific Collaboration: Providing Its "Soft" Foundations May Be the Hardest Part. . Social Science Research Network Working Paper Series 4 pp. 1-24.
[2] Merton, R. K., 1957. Priorities in Scientific Discovery. A Chapter in Sociology of Science. American Sociological Review 22 (6), pp. 635 - 59.
[3] Franzoni, C. and Sauermann, H., 2014. Crowd Science: The Organization of Scientific Research in Open Collaborative Projects. Research policy 43 (1), pp. 1-20.
[4] Ioannidis, J. P. A., 2016. Evidence-Based Medicine Has Been Hijacked: A Report to David Sackett. Journal of Clinical Epidemiology 73 pp. 82 - 86.
[5] Kreimer, P., 1998. Ciencia Y Periferia: Una Lectura Sociológica, in: M. M. (Ed.) (Eds.), La Historia De La Ciencia En El Siglo Xx Manantial, Buenos Aires.
[6] Mowery, D. C., 1995. The Practice of Technology Policy, in: P. Stoneman (Eds.), Handbook of the Economics of Innovation and Technological Change. Blackwell, Oxford.
[7] Nelson, R. R., 2004. The Market Economy, and the Scientific Commons. Research policy 33 (3), pp. 455-71.
[8] Dasgupta, P. and David, P. a., . , 1994. Toward a New Economics of Science. Research policy 23 (5), pp. 487 - 521.
[9] Mazzoleni, R. and Nelson, R. R., 2007. Public Research Institutions and Economic Catch-Up. Research Policy 36 (10), pp. 1512-28.
[10] Gagliardi, D.; Cox, D. and Li, Y., 2015. Institutional Inertia and Barriers to the Adoption of Open Science, in: E. Reale and E. Primeri (Eds.), The Transformation of University Institutional and Organizational Boundaries. Sense Publishers,
[11] Weber, S., 2004. The Success of Open Source. Harvard University Press,
[12] Fecher, B. and Friesike, S., 2014. Open Science: One Term, Five Schools of Thought, in: (Eds.), Opening Science. Springer,
[13] Grubb, A. M. and Easterbrook, S. M., 2011. On the Lack of Consensus over the Meaning of Openness: An Empirical Study. Plos One 6 (8),
[14] Schweick, C. M., 2011. Free/Open Source Software as a Framework for Establishing Commons in Science. , in: C. H. E. Ostrom (Eds.), Understanding Knowledge as a Commons. The MIT Press., Boston, Massachusetts.
[15] Nielsen, M., 2012. Reinventing Discovery: The New Era of Networked Science. Princeton University Press, New Jersey.
[16] David, P. A., 2003. The Economic Logic of Open Science and the Balance between Private Property Rights and the Public Domain in Scientific Data and Information: A Primer, in: J. M. Esanu and P. F. Uhlir (Eds.), The Role of the Public Domain in Scientific and Technical Data and Information. National Academies Press,
[17] J. K. Hartshorne and A. Schachner, 2012. Tracking Replicability as a Method of Postpublication Open Evaluation. Frontiers in Computational Neuroscience
[18] Wiggins, A. and Crowston, K., 2011. From Conservation to Crowdsourcing: A Typology of Citizen Science. Hawai.
[19] Ben-David, J., 1960. Roles and Innovations in Medicine. American Journal of Sociology pp. 557-68.
[20] Bijker, W., 1997. Of Bicycles, Bakelites, and Bulbs. Toward a Theory of Sociotechnical Change Cambrige. The MIT Press, MA.
[21] Jeppensen, L. B. and Lakhani, K., 2010. Marginality and Problem-Solving Effectiveness in Broadcast Search. Organization Science 21 (5), pp. 1016-33.
[22] Surowiecki, J., 2004. The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations Little. Anchor Books, New York.
[23] Mansell, R., 2013. Employing Digital Crowdsourced Information Resources: Managing the Emerging Information Commons. International Journal of the Commons 7 (2),
[24] Cribb, J. and Sari, T., 2010. Open Science: Sharing Knowledge in the Global Century. CSIRO Publishing, Collingwood.

[25] Aronson, B., 2004. Improving Online Access to Medical Information for Low-Income Contruies. New England Jorunal of Medicine 350 (10), pp. 966-68.
[26] Alperin, J. P., 2015. The Public Impact of Latin American's Approach to Open Access. Stanford University,
[27] Lagoze, C., 2014. Ebird: Curating Citizen Science Data for Use by Diverse Communities. International Journal of Digital Curation 9 (1), pp. 71 - 82
[28] Suber, P., 2003. The Taxpayer Argument for Open Access. SPARC Open Access Newsletter
[29] OECD, 2004. Science, Technology, and Innovation for the 21st Century: Meeting of the Oecd Committee for Scientific and Technological Policy at Ministerial Level.
[30] Gregson, J.; Brownlee, J. M.; Playforth, R. and Bimbe, N., 2015. The Future of Knowledge Sharing in a Digital Age: Exploring Impacts and Policy Implications for Development. the Institute of Development Studies, Sussex, Brighton.
[31] UN Independent Expert Advisory Group Secretary, 2014. A World That Counts: Mobilising the Data Revolution for Sustainable Development, United Nations Independent Expert Advisory Group on a Data Revolution for Sustainable Development. United Nations,
[32] World Bank, 2015. Open Data for Sustainable Development. World Bank,
[33] Catlin-Groves, C. L., 2012. The Citizen Science Landscape: From Volunteers to Citizen Sensors and Beyond. International Journal of Zoology 2012 pp. 1–14.
[34] Silvertown, J., 2009. A New Dawn for Citizen Science. Trends in ecology & evolution 24 (9), pp. 467-71
[35] OECD, 2015 Making Open Science a Reality. OECD Science, Technology and Industry Policy Papers, Paris: OECD Publishing, n.25.
[36] Stodden, V., 2010. Open Science: Policy Implications for the Evolving Phenomenon of User-Led Scientific Innovation. Journal of Science Communication 9 (1), pp. 1-8..
[37] European Commission, E., 2016. Open Innovation, Open Science, Open to the World. European Comission, Brussels.
[38] RIN/NESTA, 2010. Open to All? Case Studies of Openness in Research. Research Information Network (RIN) and National Endowment for Science, Technology and the Arts (NESTA), London.
[39] Martin, B., 2005. Strategies for Alternative Science, in: S. Fricklel and K. Moore (Eds.), University of Wisconsin Press, Madison.
[40] Delfanti, a., 2010. Users and Peers. From Citizen Science to P2p Science. Journal of Science Communication 9 (1), pp. 1-5.
[41] Burns, T. W., O'Connor, D. J., & Stocklmayer, S. M., 2003. Science Communication: A Contemporary Definition. Public Understanding of Science 12 (2), pp. 183–202.
[42] Bauer, M. W., 2009. The Evolution of Public Understanding of Science—Discourse and Comparative Evidence. Science Technology & Society 14 (2), pp. 221-40.
[43] Franco-Avellaneda, M., 2013. Museos, Artefactos Y Sociedad:¿ Cómo Se Configura Su Dimensión Educativa? . Universitas Humanística 76 (201307), pp. 97 - 123.
[44] Molloy, J., 2014. Open Training for Open Science. available at: http://science.okfn.org/2014/12/21/open-training-for-open-science/.
[45] Baden, T.; Chagas, A. M.; Gage, G. and Marzullo, T., 2015. Open Labware : 3-D Printing Your Own Lab Equipment. PLoS Biology pp. 1-12.
[46] Masum, H. and Harris, R., 2011 Open Source for Negleted Diseases: Challenges and Opportunities. Center for global health R&D Policy Assessment,
[47] Hu, M.; Schultz, K.; Sheu, J. and Tschopp, D., 2007. The Innovation Gap in Pharmaceutical Drug Discovery & New Models for R&D Success. Kellogg School of Management
[48] Robertson, M. N.; Ylioja, P. M.; Williamson, A. E.; Woelfle, M.; Robins, M.; Badiola, K. A.; Willis, P.; Olliaro, P.; Wells, T. N. C. and Todd, M. H., 2014. Open Source Drug Discovery - Limited Tutorial. Parasitology 141 (01), pp. 148-57.
[49] Årdal, C. and Røttingen, J.-A., 2012. Open Source Drug Discovery in Practice: A Case Study. PLoS Neglected Tropical Diseases 6 (9), pp. e1827.
[50] Bhardwaj, A.; Scaria, V.; Raghava, G. P. S.; Lynn, A. M.; Chandra, N.; Banerjee, S.; Raghunandanan, M. V.; Pandey, V.; Taneja, B.; Yadav, J. et al., 2011. Open Source Drug Discovery– a New Paradigm of Collaborative Research in Tuberculosis Drug Development. Tuberculosis 91 (5), pp. 479-86.
[51] Stadelmann, B.; Rufener, R.; Aeschbacher, D.; Spiliotis, M.; Gottstein, B. and Hemphill, A., 2016. Screening of the Open Source Malaria Box Reveals an Early Lead Compound for the Treatment of Alveolar Echinococcosis. PLoS Neglected Tropical Diseases 10 (3),
[52] Wells, T.; Van Voorhis, W. C.; Adams, J. H.; Adelfio, R.; Ahyong, V.; Akabas, M. H.; Alano, P.; Alday, A.; Alemán Resto, Y.; Alsibaee, A. et al., 2016. Open Source Drug Discovery with the Malaria Box Compound Collection for Neglected Diseases and Beyond. PLoS Pathogens 12 (7),

[53] Benkler, Yochai, (2006). The wealth of networks: How social production transforms markets and freedom, Yale University Press.
[54] Benkler, Y., y Nissenbaum, H. (2006). Commons-based peer production and virtue. Journal of Political Philosophy, 14(4), 394–419. http://doi.org/10.1111/j.1467-9760.2006.00235.x
[55] Lundvall, B.-Å., 1992. National Systems of Innovation : Toward a Theory of Innovation and Interactive Learning. Pinter Publishers; Distributed exclusively in the USA and Canada by St. Martin's Press, London ; New York.
[56] Arnstein, S. R., 1969. A Ladder of Citizen Participation. Journal of the American Institute of planners 35 (4), pp. 216-24.
[57] Molloy, J. C., 2011. The Open Knowledge Foundation: Open Data Means Better Science. PLoS Biology 9 (12), pp. p.e1001195.
[58] Felt, U.; Barben, D.; Irwin, A.; Joly, P.-B.; Rip, A.; Stirling, A. and Stöckelová, T., 2013. Science in Society: Caring for Our Futures in Turbulent Times. Policy briefing 50
[59] Yin, R. K., 2014. Case Study Research. Design and Methods. Fifth Edition. SAGE Publications, Thousands Oaks.
[60] Whyte, A. and Pryor, G., 2011. Open Science in Practice: Researcher Perspectives and Participation. International Journal of Digital Curation 6 (1), pp. 199-213.