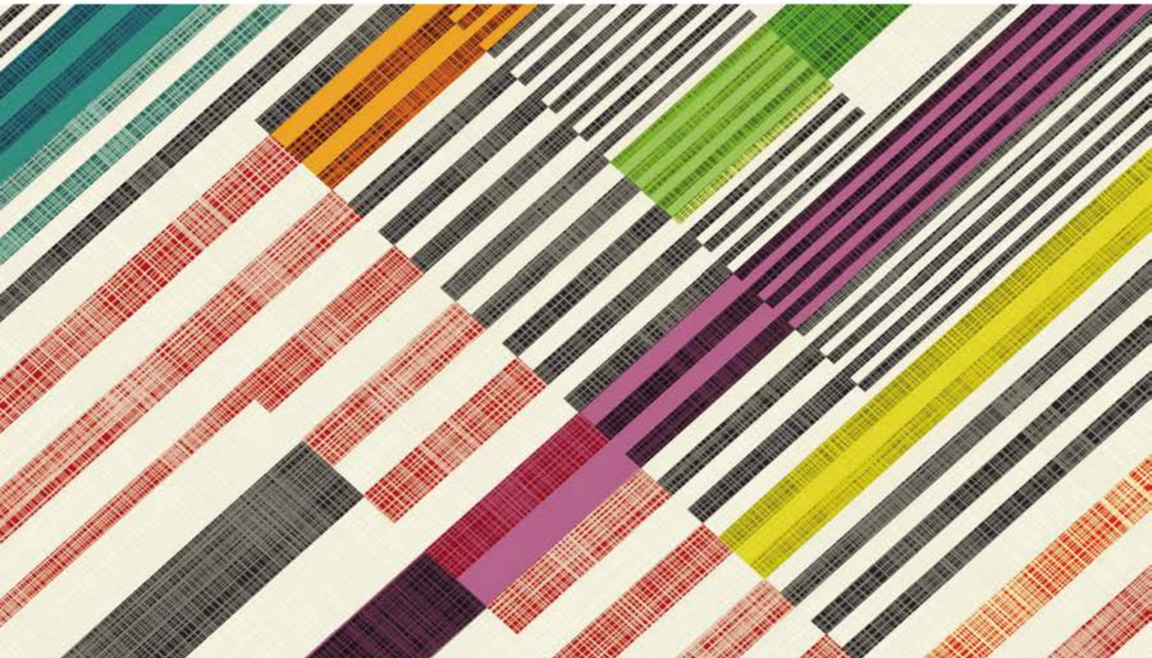
Contextualizing Openness

Situating Open Science



Edited by Leslie Chan

Angela Okune, Rebecca Hillyer, Denisse Albornoz, and Alejandro Posada

University of Ottawa Press

CONTEXTUALIZING OPENNESS

University of Ottawa **Press**
Les **Presses** de l'Université d'Ottawa

The University of Ottawa Press (UOP) is proud to be the oldest of the francophone university presses in Canada and the only bilingual university publisher in North America. Since 1936, UOP has been "enriching intellectual and cultural discourse" by producing peer-reviewed and award-winning books in the humanities and social sciences, in French or in English.

Library and Archives Canada Cataloguing in Publication

Title: Contextualizing openness : situating open science / edited by Leslie Chan; co-edited by Angela Okune, Becky Hillyer, Denisse Albornoz and Alejandro Posada. Names: Leslie Chan, 1959- editor.
Description: Series statement: Perspectives on open access | Includes bibliographical references.
Identifiers: Canadiana (print) 20190104767 | Canadiana (ebook) 20190104856 |
ISBN 9780776626666 (softcover) | ISBN 9780776626673 (PDF) | ISBN 9780776626680 (EPUB) | ISBN 9780776626697 (Kindle)
Subjects: LCSH: Communication in science—Developing countries.
Classification: LCC Q225 .C66 2019 | DDC 501/.4—dc23

Legal Deposit: Third Quarter 2019
Library and Archives Canada

Printed and bound in Canada

Copy editing	NordCompo
Proofreading	Heather Lang
Typesetting	NordCompo
Cover design	Édiscript enr.
Cover image	Shutterstock

A co-publication with
International Development Research Centre
PO Box 8500, Ottawa, ON, K1G 3H9, Canada
www.idrc.ca / info@idrc.ca
ISBN 978-1-55250-611-0 (IDRC e-book)

The research presented in this publication was carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada. The views expressed herein do not necessarily represent those of IDRC or its Board of Governors

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The University of Ottawa Press gratefully acknowledges the support extended to its publishing list by Canadian Heritage through the Canada Book Fund, by the Canada Council for the Arts, by the Ontario Arts Council, by the Federation for the Humanities and Social Sciences through the Awards to Scholarly Publications Program, and by the University of Ottawa.

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International Development Research Centre
Ottawa • Amman • Montevideo • Nairobi • New Delhi

2019

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CHAPTER 11

Negotiating Openness in Science Projects: Case Studies from Argentina

Valeria Arza and Mariano Fressoli

Abstract

Open Science promises to revolutionize the scientific model of knowledge production, and as a result, scientific and funding institutions have increasingly started to adopt its policies. However, most policies are limited to the institutional level, and, in developing countries, there are no models that inform how to build good practices of openness at the laboratory level. This chapter analyzes four cases of Open Science in Argentina, characterizing what is being opened, how, and who participates in these practices. The analysis shows that as scientists open more stages of their research, they enter into a social terrain that challenges their formal scientific norms and customs. We tentatively study this moment through the notion of boundary objects to understand how scientists negotiate meanings, tools, and several forms of communication with actors from outside the laboratory. In the conclusion, we suggest the need to identify and build exemplary cases of Open Science that allow the construction of good practices.

Introduction

Open Science is increasingly gaining attention from scientists and policy makers. Scientific institutions, funding organizations, and policy makers worldwide, such as the OECD (OECD 2015), the World

Bank (Rossel 2016), and the European Union,[1] have demonstrated interest in the practices of Open Science. In Argentina, the Law 26.899 of Open Digital Repositories, in force since 2013, and the trend to foster networked research projects provide an opportunity to adopt the tools of Open Science. Understandably, public policy and institutional recognition of Open Science seem to be focusing on technical areas where there are existing capabilities or it is easier to create them (e.g., David 2004). Therefore, institutional policies have favoured practices such as Open Access and Open Data. However, this initial process of opening up research outputs has not spread through other research stages. This approach is not unique to policy-making institutions. As the few studies about the opening up process suggest (e.g., Whyte and Pryor 2011), normally researchers do not commit to total openness but rather attempt to open up pragmatically. However, it is still not clear what aspects of the research cycle scientists and institutions are choosing to open and how—what negotiations take place?

One problem facing researchers who are inclined to Open Science is that there is no model, necessarily, that can guide them in changing their daily scientific practices. Openness and collaboration with other actors outside of the laboratory (either other researchers or citizens) undoubtedly challenge the adopted norms and customs of traditional scientific work. Also, every stage of the research process faces specific challenges in terms of infrastructure, management, and participation mechanisms, as well as risks of the undue appropriation of results. Some disciplines, such as mathematics, astronomy, and ecology, appear to be advancing more rapidly than others in the above-mentioned process.

This raises questions about the best spaces and strategies to initiate the process of Open Science, about the tools and capacities that need to be developed, and about the challenges faced by practising Open Science in different contexts. One no less important point is that most of the pioneering examples of Open Science, such as the Polymath project, Galaxy Zoo, or Foldit, which have motivated studies about Open Science, originated in universities and networks from developed countries. As the success of Open Science projects depends on factors embedded in specific contexts, these pioneering examples cannot always be directly transferred to other places. This chapter aims to understand how openness is realized in the context of Argentina, a country where the attention to science-related policy has recently grown, but investment still remains low compared with more developed countries.[2] Based on four case studies, which belong to four different networks of knowledge production, we examine what, how, and toward whom the opening process advances: when and why it takes place; what resources are necessary; and what specific capabilities scientists need to develop, and we outline the major lessons and challenges.

In Section 2 of this chapter, we discuss Open Science practices and policies. We argue that there is no clear route to follow to manage the opening-up of scientific initiatives, much less in developing countries. Section 3 presents the conceptual framework and the methodology used to analyze four Open Science projects from Argentina. This analysis is done in Section 4. Section 5 explores whether scientists construct boundary objects in the process of opening up. Boundary objects (Star and Griesemer 1989) are translation devices that connect meanings and practices across different communities. Finally, the conclusions suggest new lines of research and policy action.

Section 2: Practices and Policies of Open Science

New information and communications technologies (ICTs) have provided the opportunity to create open forms of collaboration between scientists in the definition of research problems (for example, in the Polymath project; Nielsen 2012); the participation of citizens in data classification and analysis (for example, Galaxy Zoo, Foldit; Franzoni and Sauermann 2014); or the design of software or scientific instruments for Open Science (for example, the statistical software R or the Geiger counter; Pearce 2012). Scientists are increasingly called upon to share publicly funded research outputs, such as data, publications, and infrastructure. In general, the funding agencies have demonstrated growing interest in promoting the common use of instruments that require significant investments (Sonnenwald 2007). Furthermore, there is a lot of progress in the creation of open repositories for scientific papers, although gradually repositories for data have also been developed (Gagliardi, Cox, and Li 2015).

Diverse international organizations and scientific institutions have begun to carry out recommendations and to put forward policies for the implementation of Open Science practices: for example, to open up datasets (OECD 2015; Stodden 2010), to promote access to systematic data management services (EU 2016), to acknowledge the support of open (software and tools) infrastructure (RIN NESTA 2010; Stodden 2010), and to innovate in scholarly communication practices (EU 2016). Recommendations of scientific institutions and of developmental organizations are oriented toward creating policies at the institutional level, but they offer limited guidance on how to carry out opening projects at the level of project, the laboratory, or the scientific network.

In Argentina, public policy has been almost exclusively focused on Open Access. The country was a pioneer in the region,[3] obtaining specific legislation to guarantee Open Access to publicly funded scientific outputs (through the National Law for the Creation of Digital, Institutional and Open Access Repositories that was approved in 2013 and fully in force since 2016).

However, despite these great advancements in Open Access, there is still little talk on how Open Science can move forward in other aspects of the research cycle (including citizen participation in data recollection, open peer review, public hearings). While enthusiasts from the Open Access movement initially advocated Open Access policies, it is still not clear who will push for Open Science and how scientists are going to engage in the process. As a recent study shows, scientists are not very aware of Open Science practices beyond Open Access, and there is some misunderstanding about the meaning of Open Science, although at the same time there is a great level of interest in making scientific production more collaborative and open (Arza, Fressoli, and Lopez 2017).

The lack of models or guides to follow (RIN NESTA 2010) might also reflect the cautious attitude of scientists toward openness (Whyte and Pryor 2011). At the same time, however, some opening processes can require more negotiation than others. For example, difficulties in using Open Source resources and tools, tensions between the research culture and the processes of opening, and participation of the public (Wylie et al. 2014; Riesch, Potter, and Davies 2013).

There are still a lot of challenges to the practice of Open Science, including individual and institutional obstacles (Sheliga and Friesike 2014). But, while in the European and North American contexts there is an increasing network of institutions (including scientific institutions, as well as NGOs) that offer tools,[4] protocols, and tutorials to help introduce scientists and citizens to the world of Open

Science, this infrastructure is mostly absent in Argentina, where there are neither specific programs nor support for these practices beyond Open Access.

Section 3: Conceptual Framework

In order to analyze the practices of opening the selected initiatives, we began with the characterization of RIN/NESTA (2010) on three relevant dimensions characterizing the openness of the different phases of scientific production, summarized as follows:

1) **What is opened:** This refers to which goods are put into open availability. The Open Access movement traditionally advocated for access to the final result of the scientific production process. More recently, the movements of Open Science have also focused their attention on other types of material and other phases of the research process, such as raw data, curated data, research protocols, laboratory notes, and project proposals.
2) **How is it opened (or which conditions enable the opening):** The grade and scope of openness for intermediate and final outputs of the research process vary according to several restrictions that are made more or less explicitly. These restrictions can be formal, such as the paid subscriptions or licences for the use of material or information (Molloy 2011), or informal, such as the need to obtain certain skills or complementary resources to be able to enjoy the most benefit from shared knowledge.
3) **Who participates or who are the targets of openness:** Scientists are used to sharing the final results of their research with colleagues from the scientific field, but they are less prepared to share their results with a much broader audience. The practices of Open Science have the goal of amplifying the quantity and diversity of the users and producers of scientific knowledge.

Methodology

We performed a case study analysis to understand how the processes of Open Science were carried out in concrete cases. Particularly, we aimed at analyzing the dynamics of the open and collaborative production of knowledge and data in terms of the dimensions of the research cycle that were opened, the timing of openness, the obstacles faced by researchers, and the infrastructure they used. We selected cases from a survey of all researchers working in the national scientific system, taking into account the need to cover the widest possible diversity of situations and opening processes, in terms of disciplines, processes of knowledge creation, techniques of participation, and type of infrastructure used. The selected projects are: New Argentinean Virtual Observatory—NOVA (astronomy); Argentinean Project of Monitoring and Prospecting the Aquatic Environment—PAMPA2 (limnology), e-Bird Argentina (ornithology), and Integrated Land Management Project (geography, chemistry, and environmental science). To gain information on these case studies, qualitative research methods were used, including the review of primary sources (such as scientific papers, reports, newspaper articles, and material available on the web), secondary sources, and semi-structured interviews (twelve in total, three per case), which involved scientists and technicians from the different initiatives.

Section 4: Cases of Open Science in Argentina

In this section, we present our four case studies, describing the origins and motivations of each experience, the development of the infrastructure, opening-up mechanisms, and the outcomes they obtained.

Case Study 1: New Virtual Argentinean Observatory—Nova[5]

NOVA was founded in 2009 with the aim of collecting and centralizing previously processed astronomical data in order to integrate local data to international standards, to allow its reuse, and to promote the development of astronomy. The initiative brings together the most important astronomical research centres in Argentina and counts on the support of the National Science and Technical Research Council (CONICET) and the Ministry of Science, Technology and Productive Innovation (MINCYT). The financial support allows NOVA to hire a software technician and to become part of the International Alliance of Virtual Observatories (IVOA).

NOVA gathers astronomical data in the form of images, spectrums, catalogues, measurement lists, and tables. Originally, much of this data are generated automatically by telescopes and processed later by scientists who integrate it into their analysis. However, after the analysis is done, the data are not usually re-used and sometimes are even forgotten. In addition to that, there is extensive data available in analog pictures or measurements, which are not digitized and which NOVA seeks to recover. For this reason, the aim of the project is to gather the data generated by local scientists and to make it freely available.

Until now, NOVA has mainly gathered a data collection called "Variable View of the Milky Way," which involves about four hundred million space positions. As a virtual observatory, NOVA has not required large investments in terms of infrastructure. The development of the site is based on using existing software, such as open software from the Virtual German Observatory (GADO). The greater investment was to buy a server and some personal computers to save data. Moreover, CONICET pays for the salary of a technician who is in charge of maintaining and updating the database, and of developing software applications and other tools.

Among the tools generated locally is an open software application to automatically upload and validate new pictures. NOVA also developed digital manuals and organized training sessions for astronomers to encourage the use of the NOVA site. From the beginning of 2015 until November that year, the NOVA site had about eighty-five thousand visits, of which one thousand two hundred and thirty-eight were data downloads including those from national researchers as well as researchers from other countries.

Recently, a group of scientists and students from the Laboratory of Research and Formation of Advanced Informatics from the National University of La Plata have started a citizen science initiative using NOVA Open Data. Specifically, they have begun to develop electronic games, which allow the general public to collaborate in the classification of data, such as of galaxies. One of the games allows users to discover new galaxies, which are validated later by scientists. This development is also part of a much larger project called *Cientópolis*, which aims at producing a platform for citizen science, not only for astronomy but also for other endeavours. According to Robert Gamen, director of NOVA: "The experience has been so positive…what began as a game may end up being something about which people will talk for years."

Case Study 2: Argentine Monitoring and Prospecting Project of Aquatic Environments—PAMPA2

PAMPA2 is an interdisciplinary network that seeks to understand the response of the Pampas' lagoon ecosystems to climate variability, changes in land use, and other anthropogenic effects. The central idea is that lagoons can act as "sentinels" that allow for observation of larger changes in the environment. This required a team of interdisciplinary researchers composed mostly of oceanographers, geographers, meteorologists, biologists, zoologists, and engineers to study inland water bodies selected in three provinces over a period of five years.

The network sought to create a long-term monitoring process for thirteen lagoons located along a gradient of decreasing humidity in the provinces of Buenos Aires, Córdoba, and Santa Fe. In five of the thirteen lagoons, buoys equipped with automatic sensors that measure temperature, pressure, wind, rainfall, humidity, oxygen, chlorophyll, and depth were installed. These devices are connected to a processor that stores information and then transmits it in real time to the laboratories of the network.

The data from the buoys are supplemented with other data generated by sampling in the field on a monthly or biannual basis according to the variable selected, both in lagoons that do not have buoys and in those in which buoys are already in place. These data are not open.

Since PAMPA2 is funded by CONICET, a certain level of data access must be offered. In practice, this means free availability to data produced by some of the buoys in real time (which can be accessed by anyone) and the possibility of access to bigger data sets (which generally are requested by scientists). The project does not yet have any standardized protocol on data access, although this is a current issue on the agenda of the research team.

The IADO develops and produces most of the instruments, including the automated environmental monitoring buoy in hydrology and most of the integrated sensors. In 2011, the buoy won second place in a national Innovation Award. Currently, researchers at IADO are working on a new version of the buoy that will use Open Source software. They seek to give the project an international scope and to add the collaboration of other stakeholders. The creation of PAMPA2 has enabled an increasing interaction with similar research projects around the world. PAMPA2 integrates GLEON Network (Global Lake

Ecological Observatory Network), an organization of global institutions that monitors lakes steadily through instrumented buoys. This network aims at standardizing the format of data obtained by buoys from eighty different locations, but the members have not yet reached a consensus on what database system they will use.

One of the team leaders of PAMPA2 whose group is currently involved is the SAFER project (Sensing the Americas' Freshwater Ecosystem Risk from Climate Change), an initiative that integrates scientists from various specialties from Argentina, USA, Canada, Chile, Uruguay, and Colombia that uses community-based strategies to produce knowledge. 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. However, diffusion activities have not been carried out so far because of the lack of technical and financial resources. Another obstacle is that the website that shows the data generated by the network is under construction and is not designed to receive queries from the public. Yet, researchers receive regular inquiries from people who consult the data available, for purposes such as recreation and/or production. According to Gerardo Perillo from PAMPA2:

> 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.

In this sense, as the process of opening of PAMPA2 advances, new challenges have arisen in diffusion of data, which in turn require improved infrastructure and precautions around the use of this data.

Case Study 3: Integrated Land Management Project

The Integrated Land Management (ILM) project is an interdisciplinary project that sought to study the vulnerabilities of two areas affected by severe floods in 2013 in collaboration with neighbours and institutions. These areas are the basin of the Maldonado Stream and that near a large oil refinery in Ensenada and Berisso, in the province of Buenos Aires. The aim of the project was to assess the environmental and social consequences of the floods and to propose solutions. The project was led by a group of social scientists and environmental chemists.

The project had two phases: diagnosis and implementation of solutions. At the time of our interviews, the team was well into the first phase, which aimed at doing a systematic assessment of environmental and social problems that the community recognized and required to be solved. To that end, the team articulated various techniques of natural sciences with methods of intervention from the social sciences. The expectation was that combined results from these different methods would allow the design of some solutions to existing problems, which were going to be implemented in the second stage with the participation of neighbours, institutions, scientists, and companies. This research went side-by-side with the development of technological solutions by the team of environmental chemists.

Citizen participation took part in several stages: during the design of the survey form; in the collection of rainwater to measure the pH level in order to detect the acidity or alkalinity of water; in the identification of patterns of territorial appropriation at the micro level; and in the discussion of concrete actions of intervention, among others. The analysis of all collected data was then processed and interpreted by researchers (without the participation of the neighbours).

The research outcomes have been incorporated into the repository at La Plata Environmental Observatory (OMLP). However, researchers claim that the dissemination has to be done with caution to avoid alarming or causing a negative impact on the population's beliefs and on the local authorities.

Similarly, researchers must be cautious regarding the management of neighbours' expectations since they cannot guarantee that the proposed solutions will actually take place. On their side, neighbours are also cautious about their degree of commitment to the project since this was not the first project that required their collaboration, without always delivering the expected solutions.

These precautions are illustrative of the difficulties and continuing renegotiation that a community engaged in Open Science projects must endure in order to open the research and results to a wider public. On top of this, there are further issues to be negotiated that have to do with the political context, as this is a project that is well embedded in the local authority policy agenda. For example, as there were local elections and the ruling party in the local government changed in the middle of the project's timeline, researchers needed to negotiate with the new authorities regarding what each party was expected to deliver, who in turn had to obtain approval from the neighbours.

Case Study 4: E-Bird Argentina

E-Bird is a citizen science project that receives bird sightings from anyone in any part of the world through a website and mobile phone applications. The project builds on the tradition of observation, photography, and bird conservation dating back, at least, to the late nineteenth century. It is an online platform developed in the United States in 2002 by the Ornithology Laboratory at Cornell University, which then expanded its scope, incorporating local partners in different countries. In Argentina, e-Bird was launched by the non-governmental organization Aves Argentinas in 2013. For the project, Aves Argentinas depended on the support of a network of eighty bird watching clubs. The website is maintained with the supervision of the technical staff at the institution, which has also the task of promoting and training users.

To adapt the portal for local use and launch it, Aves Argentina requested public funding, used partly in the implementation of training courses in birdwatching. E-Bird is built on the simple concept that whenever an observer grabs a pair of binoculars, he/she has the opportunity to gather useful information about the occurrence of species, migration time, and the relative abundance in a variety of locations and times. E-Bird makes use of the internet as a tool to collect, archive, and distribute information efficiently to a much wider audience.

Birdwatchers that use e-Bird to report their observations should follow a standardized protocol to load their data to ensure consistency and quality of records. Data uploaded by the users is checked in turn by a series of semi-automated mechanisms. In the case of unusual uploaded data, these are reviewed by a designated expert who controls its veracity. In Argentina, in addition to the four people who work for Aves Argentinas, twenty amateur experts collaborate in data verification.

Every e-Bird local portal is integrated within the infrastructure of applications and the database located in the United States. Despite this centralization, e-Bird is an open platform. This allows, for example, any user to have access to simple data from the website. In the case of large volumes of data, it can be requested for free from e-Bird in the US, and the data are returned by email. In addition, Aves Argentinas and its funders made an agreement to join the National Biological Information System (SNDB) that involves a commitment to incorporate data from e-Bird to SNDB.[6]

Data gathered by e-Bird that provides information on the spatial distribution of species and allows the possibility of tracking population trends, also help in identifying areas or important sites for the conservation of birds. Thus, e-Bird might contribute to the design of better management plans for the recovery of threatened species or for those in danger of extinction. At the same time, these data can be used for scientific purposes to study the distribution patterns and movement of birds throughout Argentina, including migration routes, wintering and breeding areas, etc. At this time, it allows amateur observers to know more about birds in the region they inhabit and assists in tracking their personal observations.

In little more than two years of operation, the e-Bird Argentina project achieved the detection of approximately nine hundred and sixty-seven thousand different species, which is approximately ninety-five percent of the species that exist in Argentina. It is likely that this collection would not have been possible without the participation of hundreds of enthusiastic citizens who contributed their data.[7]

Characteristics and Scope of Openness

Following the concepts presented in the introduction, in this section we look to understand the characteristics of the process of openness, how it has evolved, how obstacles are overcome, and which stages are opened and why.

What Is Being Opened: Data, Infrastructure, and Citizen Participation

The four cases have the common goal of opening data for re-use by scientific networks and by citizens—although they have had different results in doing so. In the case of NOVA and PAMPA2, the release of data is mainly based on the international practices of their respective disciplines. Part of the incentive of opening up these cases is the ability to share data and research on a reciprocal basis with researchers and international institutions. In the case of e-Bird, the incentive for opening is different because data producers are not scientists, but citizens—thus, opening works as an incentive to share data in a community of peers, even if researchers in various disciplines also use the data. In these three cases (NOVA, PAMPA2, and e-Bird), institutional support in the data opening process was provided mainly by their public funders, without the need for an imposition of a plan as to how the data should be released. In the case of ILM, the situation is reversed since there is no obligation to open the data. Although as part of the Environmental Observatory of La Plata, the data would eventually be public, but, at the time this research concluded, data was not yet made open.

A second point in the opening process is infrastructure, in particular, open software. Both NOVA and e-Bird Argentina took advantage of existing open software and made local adaptations using minimal resources. In the case of PAMPA2, researchers took advantage of the expired patents for the assembly of the first monitoring buoys. Later, as it was time to advance a design for new buoys, the use of open software began to be considered as a way of improving collaboration and for resolving problems.

The third focus of openness is the citizen participation in the collection of data. In e-Bird, citizen science constitutes the basis of the project. In contrast, in ILM, the citizens helped to collect some of the data regarding water quality and also to refine the questionnaires, as well as suggesting the best locations for the research. In the other cases, citizen science tools were used only once the project had begun. In NOVA, the opening to citizen participation took place in the context of an informatics workgroup, created within the university that led NOVA, called *Cientópolis*, whose objective was to create a platform for the development of citizen science projects. Similar to Galaxy Zoo (Franzoni and Sauermann 2014), *Cientópolis* has built electronic games, such as the Galaxy Conqueror, that allow users to classify galaxies. PAMPA2 does not experiment with tools for citizen science data collection, but its associated project, SAFER, does. This project has an educational component and works with students from a middle school who collect data to help the research team.

How It Is Opened: Participation and Barriers to Access

The conditions under which the opening process takes place vary according to the objectives and the requirements of data production for each initiative. In the case of NOVA and PAMPA2, data are mostly produced by scientists and for scientists. Therefore, the opening protocol establishes a period of embargo on new data that can last until the publication is complete. However, once this embargo period is over, data are made freely available for use and analysis by other researchers. Nonetheless, in the case of PAMPA2, some of the data obtained during the day can be observed for free on the project website. E-Bird also offers Open Data to the general public on a large scale. However, similar to PAMPA2, the use of large datasets are granted by the website administrator only upon request.

Some of the available data are simple and do not require prior knowledge to make the most of them (PAMPA2 and e-Bird). In the case of NOVA, access to data is free, but requires expert knowledge of astronomy and specific software tools used by the project. The development of the game Galaxy Conqueror seems to aim at alleviating this barrier, at least partially, making data available to allow greater interaction with the public. In the case of ILM again, the conditions for access to the data are limited due to the complex political situation of the floods in the region and the fear that this information could trigger false expectations among the public. Indeed, this last case suggests that the negotiations of openness in the case of politically sensitive information are more complex and mediated differently than other scientific projects.

For Whom It Is Opened: Uses and Benefits

The four cases have implemented some form of Open Access that eventually would allow data to be re-used by other scientists. However, there is little evidence that this is happening at the local level, in contrast with international cases. For instance, in the case of e-Bird, data available from Cornell's servers have been used by researchers in various disciplines, including landscape, ecology, macro-ecology, computer science, statistics, and human computation. Data from NOVA have also been shared at the international level, but so far there is no track of papers published using the Argentine data. In PAMPA2, although some difficulties remain in collaborating across different disciplines, the group has published jointly, including a special journal issue.

Besides scientific collaboration, the four cases show different degrees of openness to public participation as users and/or producers of data. The clearest case is, of course, e-Bird, in which the public plays an important role in data collection and is also a key user of data. Similarly, ILM has involved the public in certain aspects of the research cycle like data collection and questionnaire design. In turn, NOVA (*Científopolis*) and PAMPA2 (SAFER) are also making efforts to involve the public in the use and production of data. Because this level of openness is under construction in both cases, it is difficult to say how participation will be promoted; it might require the development of new infrastructure (i.e., processes, data validation, and use of social networks more intensively).

Section 5: Negotiating Openness Through the Construction of Boundary Objects

The cases allow us to understand how scientists in Argentina take advantage of the scarce available support from policies and programs in order to explore new forms of openness in other stages of the research cycle. Thus, the opening process is not limited to Open Access and collaboration among scientists from a project and/or discipline, but it is slowly opened to other forms of collaboration with scientists and the public in general. This tendency hints that there might be great potential to extend the practices of Open Science in the country. At the same time, we noticed that opening attempts are gradual and differentiated by the stages of the research process. In this sense, these cases also offer some insights into the limitations and challenges that local scientists suffer when trying to open other stages of the research cycle, due to the lack of tools and the capabilities available for such tasks.

In the cases analyzed, the opening process does not follow an established plan; some of the practices of openness are created in the making. More importantly, as scientists open their data and tools to collaboration with other actors in society, they begin to enter a field that is not always familiar and that can challenge the rules and customs of scientific practice. In this sense, the negotiation phase of the opening process is similar to the construction of boundary objects (Star and Griesemer 1989). This notion was originally developed by

Star and Griesemer (1989) to understand how scientists, conservationists, and amateurs translate different ways of producing information at the Berkeley Zoological Museum of Science. Extending the original use of this concept a little, in the following sections we explore briefly how scientists build boundary objects to negotiate opening on three levels: tools and infrastructure, data to other experts, and communication and dissemination.

Tools and Infrastructure

Opening access to data and the process of collaboration often requires building new infrastructure and technical tools such as software, databases, web pages, and sensors. In practice, this means contacting experts from other areas and communities who respond to quite different aims and rules (such as software programmers, makers, etc.). In two of the analyzed cases, it was possible to see how building these elements was made easier by the availability of open software tools (e.g., NOVA, e-Bird). In the case of PAMPA2, they have recently started to build a new instrument using open software. However, this presents some challenges since the scientists do not always have the capabilities to use and develop this kind of tool. They sometimes have to learn the basics about Open Source software, create new data protocols for Open Access, and begin to understand what data can be made public and what cannot. Beyond the need to develop these capabilities, scientists do not always have the required resources and technical support to develop basic tools such as a web page. Therefore, some of the advances in the process of opening up science are often done *ad hoc* and based on the goodwill of scientists.

Collection and Opening of Data

Similar to the description by Star and Griessemer (1989), standardization and simplification of data, such as the construction of simple forms of visualization, are key tools that allow the use of data by other actors. The same applies to the processes of data collection by citizens, where the development of simple protocols is essential to facilitate public participation. In the case of SAFER (PAMPA2 sister project) and ILM, inviting public participation required the construction of a minimum instrument, and in the case of e-Bird and *Cientópolis* (NOVA sister project), recreational development tools like games and quizzes. Translating the data collection and use into accessible formats can be seen as a challenge. This implies negotiating different meanings and uses of the data with potential users. However, these are also areas of expertise that are rare in scientific labs and scientific institutions but need to be considered in Open Science plans at the institutional level.

Communication and Diffusion

Project visibility is needed to motivate participation and collaboration of diverse actors (e.g., Benkler, Shaw, and Hill 2015). Inviting them to collect data or to collaborate in the design of instruments often requires participatory techniques and communication strategies such as the use of social networks (Lasky 2016). Again, to do this, scientists need to build skills or learn from experts who do not necessarily belong to their scientific field and who are not funded by scientific funding schemes. NOVA has done so at the expense of personal efforts of one of its leaders, who is active on social networks. In turn, e-Bird relies on the international recognition of the initiative and its experiences in organizing competitions, day fairs, etc. PAMPA2 and ILM claimed not to have the resources to do so, although at least the former openly stated they believe it is an important activity.

The central point is that the construction of boundary objects introduces scientists to new fields: (1) relational fields that allow interaction with scientists in other disciplines and with the general public; (2) a technological field that facilitates the development and use of new open technologies; and (3) a management field that allows the coordination of several activities and actors participating in Open Science projects. In these new fields, scientists constantly need to negotiate their knowledge, capabilities, and actions. This negotiation varies across the different fields and also within activities in each of them. It is likely then that the learning processes required to build the necessary boundary objects to enter new fields include not only the accumulated skill sets of scientists, but also their learning capacities to conquer the new tools of open infrastructure, public communication, and management of social networks.

Conclusions

Open Science policies can benefit from the study of exemplary cases. We believe it is important to systematize benefits, challenges, and obstacles experienced by different Open Science initiatives in Argentina. This can help with the creation of an action plan for initiatives that are keen to join the Open Science caravan. As we have seen, the opening process is usually progressive and diverse. It is therefore essential to have a variety of cases that develop a set of good practices. The study of the construction of boundary objects can help in understanding how scientists learn to negotiate their interests and practices during the opening process. In particular, it is important to note that the further scientists engage in the opening process, the more capabilities and tools they will need. Scientific institutions and policy schemes are currently providing neither one. Policy makers might need to consider better policy design to promote Open Science.

Notes

1. See the Open Science Policy Platform set up by the European Union since 2016 at https://ec.europa.eu/research/openscience/index.cfm?pg=open-science-policy-platform.
2. The policy area on Science, Technology, and Innovation reached the rank of a Ministry in 2007. It was previously managed by a secretariat dependent on the Ministry for Education. The higher rank in the Government Organization Chart was highly symbolic, and it correlated with a switch in the policy and media discourse promoting science, technology, and innovation as necessary tools for development. The national spending on R&D has also increased continuously both per capita and as a percentage of GDP, at least until 2012, when economic recession became evident. Both indicators climbed from USD 40.8 and 0.46% in 2007 to USD 90.26 and 0.64% in 2012. In 2014 (latest data available), they were USD 80 and 0.59%. These figures are among the largest in the region, only surpassed by Brazil (USD 147.1 and 1.2% in 2013), but they are quite low when compared with those from United States (1443.9 USD and 2.73% in 2013) or even Spain (342.6 USD and 1.2% in 2014).
3. Peru was the only country in the region with similar legislation, also approved in 2013. The national repository there is called National Open Access Repository of Science, Technology and Innovation (*Depósito Digital Nacional de Ciencia, Tecnología e Innovación de AccesoAbierto*). http://alicia.concytec.gob.pe/vufind/.
4. For a brief guide of available tools for Open Science, see https://www.cientopolis.org/herramientas-de-ciencia-abierta/.
5. The case study of NOVA is based on the work by Rodriguez, F. (2015). Nuevo Observatorio Virtual Argentino—NOVA, in Arza, V., and M. Fressoli (ed.), *Proyecto: Ciencia abierta en Argentina: experiencias actuales y propuestas para impulsar procesos de apertura*. Retrieved from: http://www.ciecti.org.ar/wp-content/uploads/2016/09/CIECTI-Proyecto-CENIT.pdf.

6. However, there are interoperability issues that have hampered the process of migration of Argentinean data from the e-Bird server in the US to SNDB's servers in Argentina. Aves Argentinas is searching for a technical and/or managerial solution to this problem.
7. Globally, the volume of data collected by e-Bird increased exponentially in a period of ten years, 30–40% annually between 2003 and 2013 (Sullivan et al. 2014). By mid-2013, one hundred and forty million observations were collected from one hundred and fifty thousand separate observers, who spent 10.5 million hours collecting data (Sullivan et al. 2014).

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