13 Toward an Inclusive, Open, and Collaborative Science: Lessons from OCSDNet

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

Introduction

The idea of *open science* has gained momentum over the past few years, emerging alongside other open initiatives—including open access, open government, open source, open data, and others (Bartling and Friesike 2014). A common conception of open science is the opening of the entire research cycle, from designing the question and methods, to collecting and analyzing data, through to the communication and dissemination of the findings (Fecher and Friesike 2014; Nielsen 2013). In principle, these practices allow increased transparency of scientific processes, as well as the expansion of participation in and opportunities for diverse forms of knowledge production. As such, open science provides a key opportunity to critically reflect on who is involved in knowledge-making processes, what tools are used, and what forms of knowledge are being produced and legitimized. Ultimately, open science provides a unique lens for understanding how science could be made fairer to and more inclusive of groups and worldviews that have been previously marginalized from scientific discourses.

Despite this potential, the majority of action and discussion on open science has been dominated by actors and institutions in the Global North, with a tendency to concentrate on the tools, infrastructure, and cost models of producing knowledge openly (OECD 2015; Orth, Pontika, and Ball 2016; Schmidt et al. 2016), with less focus on the underlying power structures that tend to determine who can or cannot participate in knowledge-production processes, and for what aims (Chan et al. 2015; Czerniewicz 2015; Graham, Sabbata, and Zook 2015; Moletsane 2015; Okune et al. 2016; see also chapter 5 in this volume). In such a framing, openness has become a universal set of technical requirements and standards to be met,[1] rather than a dynamic process of negotiation between knowledge producers within particular social, historical, and institutional contexts.

The Open and Collaborative Science in Development Network (OCSDNet) is an international research network launched in 2015 to address the fundamental question

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of whether and how open science has the potential to contribute to the achievement of development goals and opportunities (Chan et al. 2015; Chan et al. 2019). Funded by Canada's International Development Research Centre (IDRC) and the UK's Department for International Development (DFID), with coordination support from iHub[2] (based in Kenya) and the University of Toronto, OCSDNet is composed of twelve international research teams[3] throughout Latin America, Africa, the Middle East, and Asia. The teams are composed of individuals with highly diverse academic and practical backgrounds, including in law, art, education, climate change, the maker movement, intellectual property rights, biodiversity, health, and environmental conservation. Over the course of two years, and using an array of diverse research methods, each team explored the challenges and opportunities for imagining science as open and collaborative, as well as the potential of open science to contribute toward inclusive and sustainable development in their local contexts.

OCSDNet recognizes that in recent history, the processes of knowledge production and dissemination have been shaped and solidified by a privileged and exclusive set of actors who have influenced how the world understands valid and legitimate scientific knowledge and research. This limited representation of knowledge has led to an incomplete and distorted understanding of the world and the issues affecting local populations (Moletsane 2015; Sillitoe 2007). Unchallenged, this system will continue to entrench knowledge and research inequalities and will have serious consequences for sustainable and equitable development (Hall and Tandon 2017a).

This chapter synthesizes the lessons from the twelve projects within the network, which have shaped how the OCSDNet members have reimagined the potential of open science to transform knowledge production and contribute to sustainable development. It is important to note the diversity of projects across the network. Some projects have contributed to the practice of open science at the grassroots level by implementing small-scale citizen science projects at the community level. Other projects have contributed to reimagining the field through case-study analysis of existing, longer-term open science initiatives by unpacking the challenges and social tensions that can arise as openness scales up within or between institutions and their networks. Finally, other research teams have applied network-defined open science principles within their unique contexts to develop new tools and frameworks for understanding how open science contributes to complex development and societal challenges.

The chapter begins with a discussion of the network's background, including the methodologies that have guided the research conducted between 2015 and 2017. This is followed by an overview of how individual projects have contributed to coconstructing a new and more nuanced understanding of open science. Through the application

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of a contextualized or situated approach to defining and practicing open science, the chapter concludes with key lessons for making the theory and practice of open science more amenable to a diverse set of actors and epistemic traditions in the achievement of development objectives.

Conceptual Framework and Methodologies of OCSDNet

The initial research questions for the network were based on the Institutional Analysis and Development (IAD) framework developed by Elinor Ostrom and her colleagues, which is grounded in the assumption that knowledge is a common community resource.[4] Ostrom's work challenged conventional wisdom around the need for government regulation of public resources (such as forests and fisheries) in order to attain sustainability and benefit sharing, highlighting that communities often formulate their own rules and procedures for governing shared resources without top-down intervention (Ostrom 1991, 2005).

More recently, the IDA framework has been applied to knowledge as a commons that cuts across national and disciplinary boundaries (Hess 2012; Hess and Ostrom 2005), which makes it distinct from natural resources. Frischmann, Madison, and Strandburg (2014) developed a "knowledge commons framework" to aid researchers with empirical research on different forms of commons. The concept of the commons also includes open-source commons (Schweik and English 2012), art commons (Guayasamín and José 2014), and medical knowledge commons (Strandburg et al. 2017). The revised framework provides guiding research questions around the types of communities, the resources in use, the existing institutional arrangements, and the interactions that take place within the community. These questions were used and adapted by OCSDNet projects to structure data collection activities, and also provided valuable information about how different groups, institutions, and cultures might implement principles of openness differently.[5]

The bulk of the data collected from OCSDNet projects came from monthly and annual reports, project publications, interviews with team members, and group discussions throughout the funding cycle of the network. However, less structured observations around team and network working dynamics were drawn from exchanges within a closed Google Group[6] established for network communication, as well as from discussions on social media (e.g., Facebook groups and Twitter), while also including participation in various public speaking forums, including academic conferences. Project teams were encouraged to share events, resources, and best practices as part of the field and network-building exercises.[7]

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OCSDNet also explored the potential of participatory, consensus-building exercises through the design of an *OCSDNet Manifesto*, which consolidates the shared values and understanding of the importance of open and collaborative science to scientific research and development.[8] These discussions and the subsequent seven open science principles that were developed have influenced the way that projects assess their findings and ways of working.

OCSDNet's diverse geographies, skill sets, and epistemologies required a different kind of rigour (Chambers 2017, 91) beyond a Newtonian cause-and-effect epistemology that anticipates predictable, linear change. "Inclusive rigour" (Chambers 2017, 94) acknowledges the complexity of research for development and focuses on "critical observation and analysis of the processes of knowledge formation, including distortions resulting from power relations… positionality, relationships, and interactions" (Chambers 2017, 98). The core concepts of this approach include eclectic methodological pluralism, diversity and balance, improvisation and innovation, adaptive iteration, triangulation, and inclusive participation for plural perspectives. OCSDNet employed this approach in its analysis to uncover themes and ideas and to allow a broader comparison among diverse and complex projects. As a result, the cases reveal innovative ways that open science principles can be applied to complex development questions and scenarios, and also include the sociocultural contexts that enable (or curtail) open science as an effective approach for achieving sustainable development objectives.

Furthermore, OCSDNet members broadly agreed on a notion of development that builds on Appadurai's (2006) "Right to Research," which acknowledges that all humans have the capacity to imagine their own knowledge and future. This echoes Amartya Sen's Capabilities Approach, which suggests that human development is the process of enlarging a person's "functionings and capabilities to function, the range of things that a person could do and be in her life," expressed in terms of one's agency to exercise "choice" (Sen 1989, 48). A primary goal of development is thus to improve human lives by expanding the range of things that a person can be and do, such as to be well nourished and healthy, to be knowledgeable by taking part in *making* knowledge, and to participate actively in community life. In this regard, the Latin American and Indigenous tradition of *buen vivir*[9] (meaning "good living" in Spanish) and the African concept of Ubuntu (which celebrates the strength of humans working and living in community with one another) both informed the network's conceptual framework (Dolamo 2013).

OCSDNet also recognized that inclusivity and cognitive justice are both key for open science and to achieve development objectives that are fair and meaningful for a broad array of groups, particularly those who have been historically marginalized in

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knowledge-creation processes. Inclusivity is actualized through questioning and reflection, and cognitive justice "demands recognition of knowledges, not only as methods but as ways of life" (De Sousa Santos 2014; Visvanathan 2009), to ensure that all people have the right to access and create locally relevant knowledge with epistemologies, tools, and modes of collaboration of their choice.

Taken together, these ideas comprise a framework of inclusive development that positions human beings as agents working toward common goals, using tools and forms of knowledge that are most relevant to their unique sociocultural contexts.[10] It is in this context that we assess whether the practice of open and collaborative science has the potential to achieve positive development outcomes.

The next section will discuss key findings from the twelve individual research projects. The intention is to frame open science beyond the tools and cost models commonly associated with working openly.

Findings from OCSDNet Projects

The diversity of the network afforded a unique opportunity to interrogate the manifestation of open science practices ranging from the grassroots community level to the institutional, national, and regional levels. While some teams sought to implement practical, hands-on open science projects with tangible development outcomes for local communities, others analyzed and documented the challenges and implications of existing, longer-term open science initiatives, or developed new tools, modes of collaboration, and theoretical frameworks that explore open science as an inclusive approach to development. As such, the projects have been divided into three categories, with the intention of viewing open science from the perspective of (1) the local grassroots level, using an insider approach (four projects); (2) the metalevel outsider view to understand the challenges of scaling and sustaining larger open science projects (two projects); and (3) by exploring the potential of open science principles in the creation of new tools and frameworks for addressing local development issues (six projects).

Practicing Open Science at the Grassroots Level

Grassroots development refers to development activities driven by local communities. It facilitates a bottom-up approach to development, which allows ordinary people to be directly involved in activities meant to improve their lives (Escobar 1992). OCSDNet borrows from grassroots development because it is similar to the localized and small-scale citizen science initiatives that exist in four of the projects, which allowed people

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to initiate, manage, and assess community-based open science initiatives with minimal funding and in a relatively short time frame. They permit a unique, insider perspective regarding the day-to-day negotiations and complexities associated with the practice of open science, as well as a chance to compare dilemmas and opportunities across contexts. Most important, they provide the opportunity to assess whether the small-scale, open science project approach could have positive implications for sustainable community development.

All four projects in table 13.1 position citizen science as central to their respective methodologies and conceptual frameworks. In general, *citizen science* refers to "the involvement of the public in scientific research—whether community-driven research or global investigations" (Citizen Science Association 2017).[11] Although numerous forms of citizen science may have important outcomes for knowledge production and development, they do not always acknowledge members of the public as local experts or co-researchers who could provide valuable insight during all stages of the research cycle.

All four projects use participatory action research (PAR) methodologies in their research design and data collection.[12] PAR methodologies tend to position citizens as local experts who are likely to be involved in all (or many) stages of the research cycle that include the identification of local challenges, research design, data collection, analysis, implementation, and communication of results. Within OCSDNet, there is a

Table 13.1
Practicing open science at the grassroots level.

OCSDNet project name	Keywords
Water quality and social transformation in rural Kyrgyzstan	citizen science, environmental conservation, Kyrgyzstan, open science motivation, participatory action research, rural communities, water quality, students, teachers
Community-driven environmental conservation in Costa Rica and Colombia	adaptive capacity, biodiversity, citizen science, Colombia, Costa Rica, human capabilities, Model Forests, participatory action research, sustainable development
Water quality and community development in Lebanon	bottom-up policymaking, citizen science, community-based environmental management, empowering conservation, Lebanon, participatory action research, water quality
Open science hardware for development in Southeast Asia	citizen science, do-it-yourself, Indonesia, little science, Nepal, open science hardware, participation, right to science, Southeast Asia, Thailand, tinkering, tools, transnational networks

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strong overlap between the use of PAR methodologies and the intentional practice of citizen science and, as a result, citizen scientists involved in network projects were often engaged in various capacities throughout stages of the research cycle. For instance, in Kyrgyzstan, the OCSDNet research team worked with rural schoolteachers and students to design an experiment for testing local water quality after communities acknowledged that water pollution was a significant issue in the area. This was not a simple act of designing and rolling out an experiment, but instead involved complex discussions with teachers, students, and research organizations that focused on who should be able to participate in scientific knowledge production, and for what purposes. Throughout the project, teachers and students began to redefine their ideas of who a scientist is and what scientific research could entail.

This was similar to the research team in Lebanon, which recruited a group of local volunteers (all of whom were women) to conduct water-quality testing in fifty rural villages. After intensive training to equip them to use specialized tools, the women located problematic wells and conducted water-quality analysis. Through these activities, not only did these citizen scientists feel more informed about water issues in their respective areas, they felt empowered to begin making demands on the government to pay attention to water-quality issues.

In the case of the projects based in Costa Rica and Colombia, citizen science was negotiated differently. Here, the team sought to bring together local community members and academic researchers to discuss and negotiate how the Model Forest[13] approach to sustainable development could be adapted in the context of open science. Input from both parties was used to construct opportunities for collaboration and knowledge-sharing to achieve local development goals. In the end, seven new, community-based open science initiatives were devised around the theme of local adaptation to climate change, including a farming agroecology network, a rainwater harvesting program, a tree nursery, and ecotourism awareness.

For the fourth project based in Southeast Asia, a more subtle version of citizen science was enacted in order to facilitate and assess project activities, through what the team refers to as *small science*. This team built on the practice and philosophy of the increasingly popular global maker movement and hacker communities, which position the creative building and codesign of tangible tools and processes for innovative problem-solving. Using these concepts as a starting point, the team hosted four multiday workshops that brought together a diverse group of participants (including artists, designers, students, and teachers) to test opportunities for facilitating creative spaces, which would allow participants to identify and discuss issues of importance to the local communities, as well as the potential to develop strategic tools for addressing these challenges.

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As a result of these exchanges, the team suggests that, within their context, open science could be imagined as a process of creative engagement among diverse participants, often without a tangible social or development objective in mind. One interesting cross-project outcome from these exchanges was the design and construction of a cost-effective microscope, which was taken up by the OCSDNet team in Kyrgyzstan for use in rural schools with underresourced science labs.

The first two projects in Kyrgyzstan and Lebanon highlight instances where, given the opportunity to participate in processes of creating and analyzing locally relevant knowledge, otherwise-marginalized communities used their knowledge to address a pertinent local challenge and altered the way that they feel about themselves as active and informed citizens within their communities. Additionally, given the notable voluntary participation from women (in Lebanon) and female schoolchildren (in Kyrgyzstan), the research suggests that a local, exploratory approach to open science could be a means for increasing the representation of women and girls in scientific initiatives.

Overall, the four projects highlight the nuances of positioning citizen science in the context of open science in development, the specifics of which vary depending on the theory of change used by the individual project. In all instances, the framing of who are citizen scientists and what role they play within a given project has important implications for assessing who has power within the scope of the research cycle, and hence who has the power to create relevant, local knowledge. To varying degrees, all four projects were designed to increase opportunities for regular citizens to participate in processes of knowledge creation and discussions that could have implications for influencing their lives. Importantly, each project sought to challenge the traditional idea of who constitutes a scientist and to reimagine the tools and processes required for legitimate scientific discovery and local innovation. Finally, all four projects position citizens as agents of change with important, preexisting expertise, rather than as mere volunteers involved in data collection for a preestablished project agenda.

These factors all demonstrate the ability to engage in inclusive open science. These projects worked with diverse actors who otherwise would tend not to be involved in the creation of scientific knowledge and/or would be unlikely, as defined experts, to be involved in knowledge creation with local communities. They were able to do so through collaboration and learning across disciplinary silos, and they do not follow the technocratic, instrumentalist, top-down route of previous development initiatives.

Analyzing Existing Open Science Projects

Two projects within OCSDNet sought to examine the challenges and opportunities for larger, complex, ongoing open science initiatives that extend beyond two to three years of funding. These projects provide insight into the complexities and longer-term

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Table 13.2
Analyzing existing open science projects.

OCSDNet project name	Keywords
Evaluating open science e-infrastructure in Brazil	botany, Brazil, e-database, interdisciplinary collaboration, open science infrastructure, virtual herbarium
Negotiating open science in Argentina	Argentina, boundary objects, negotiating openness, opening process, open science

challenges of existing open science projects in the Global South, both for individuals and institutions, as well as the practical implications that these challenges could have for achieving sustainable development through the practice of open science.

In the Brazilian case study, shown in table 13.2, the research team sought to understand how and for what purpose diverse users were accessing a Brazilian-based, open access e-database, and documented any benefits to data providers. Known as a virtual herbarium, the open access database consists of pooled botany and fungi records from a large network of Brazilian research institutions. The initial idea behind the virtual herbarium was to create a centralized hub of information that could be easily accessed by any individual interested in research on Brazil's rich and diverse plant and fungi kingdoms. The herbarium was initiated in 2008 and is currently composed of 106 associated national herbaria, 25 herbaria from abroad, and 20 other herbaria that are not directly associated with the project but contribute their data through a shared provider. As a whole, the e-infrastructure combines over 5.5 million data records from 191 data sets and more than 1.4 million images (Canhos et al. 2015).

The OCSDNet research team recorded impressive results around the use of herbarium records, documenting not only the surprising frequency with which data is accessed and used (1.7 billion records were accessed between 2012 and 2017), but also the diversity of the users ranging from PhD, master's, and secondary school students, to government representatives, local research organizations, nongovernment organization (NGO) workers, and the private sector. Importantly, 94 percent of users were residents of Brazil, highlighting the immense importance of providing access to local knowledge through accessible, online tools in local languages.

Most surprising to the team were the complex negotiations and cultural shifts that occurred over the years that supported the project's success. For instance, the preliminary requirement for data providers was the complete openness of all data—but through a series of negotiations, this requirement changed to allow data providers flexibility in deciding which records would be made openly available and how. This was largely in response to one of the larger data providers, who felt that full data availability through the virtual herbarium reduced visitor traffic to its own site, hence diminishing

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its own reputation. At the same time, all decisions regarding the technological aspects of the network's architecture and e-infrastructure were left to those equipped with the relevant technical skills. It seems that it was important for key actors to have some degree of power over their contributions to maintaining the herbarium, while also having appropriately defined roles that allowed efficient, longer-term planning and governance of the infrastructure. Communication, transparency, and participation, according to the team, were indispensable for building trust, understanding, and ownership among all actors.

In the Argentinian study, the team assessed four locally initiated open science case studies encompassing a broad range of disciplines—namely, the New Argentinian Virtual Observatory (NOVA) (astronomy), Argentinian Project of Monitoring and Prospecting the Aquatic Environment (PAMPA2) (limnology), e-Bird Argentina (ornithology), and the Integrated Land Management Project (geography, chemistry, and environmental science). The team sought to understand what is being opened within the specific cases, how it is being opened, and who is participating in the opening process. They were particularly interested in understanding the consequences of scaling up open initiatives and how the transition from the laboratory to the institutional level occurs in practice, particularly because institutional models of open science do exist, but there is usually less emphasis on the initiation of openness at the laboratory level.

The team noted in its analysis that while the four Argentinian case studies employed different methodologies and actors for the collection of data, all strove to make collected data more accessible to the general public. Furthermore, their findings suggest that as each of the four open science case studies moved to a new phase of the research cycle (from project planning to data collection to analysis to dissemination), there was a need to reflect on and reconsider the tools, resources, and infrastructure required for each new phase. At these junctures, open scientists are forced to create and confront boundary objects (i.e., tools and/or forms of communication that allow for the translation of complex ideas across diverse communities). From a sociocultural perspective, this process puts new strains on open science practitioners, as each phase may entail new contradictions of (and hence negotiations with) traditional institutional norms and structures.[14]

Looking at both the Brazilian and Argentinian case studies, several key observations can be made regarding the complexities of sustainable, longer-term open science initiatives. First and foremost, effective open science is more than the design of new tools that allow easier collaboration among individuals. Instead, it demands complex negotiations around roles and responsibilities, principles and priorities, and timelines and resources. Second, open science practices require new and innovative thinking at each stage of the research cycle and reflection on how such practices may coincide with existing cultural

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and institutional norms. Third, from a practical perspective, large-scale initiatives also require a comprehensive consideration of long-term funding, particularly when multiple institutions are involved. Indeed, despite the success of the Brazilian virtual herbarium and its deployment since 2008, the infrastructure is still described as a project because the sustainability of funding is by no means a guarantee (Canhos et al. 2015).

Exploring the Potential of Open and Collaborative Science through New Tools and Frameworks

Other OCSDNet teams imagined the potential of open science through a variety of new tools and frameworks. Two teams drew on network principles of open science to create new, practical, and usable tools to negotiate complex development issues within their specific contexts, while four other teams used these principles to develop new ways of framing possibilities around open science to address particular local challenges (see table 13.3).

In the case of new, practical, and usable tools, the OCSDNet team in South Africa employed open science ideologies to negotiate a community-researcher contract to

Table 13.3
Exploring the potential of open science through new tools and frameworks.

OCSDNet project name	Keywords
Researcher contracts for Indigenous knowledge in South Africa	climate change, decolonizing research methodologies, Indigenous knowledge, intellectual property rights, research contract, South Africa, terra nullius
Disaster management tools for small island-states	design science, disaster recovery plans, knowledge broker artifact, regional collaboration, Small Island Developing States,
Commercialization and open science in Kenya	collaboration, commercialization, Kenya, IP laws, open science, private sector, research partnerships, universities
Sustainable development and the potential for open citizen science in Brazil	diverse actors, open science, participatory action research, social change, sustainable development, Ubatuba
Social problems and the potential of open science in Latin America	cognitive exploitation, collaborative science, Latin America, nonhegemonic countries, openness, social problems
Building open science social networks in West Africa and Haiti	cognitive justice, Haiti, open repository, open research, open science networks, participatory action research, science shops, West Africa

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safeguard Indigenous communities' knowledge around climate change and adaptation. Originally, the team planned to investigate what climate knowledge exists within Indigenous communities (and hence what knowledge might be openly shared) to promote learning around adaptation to climate change. However, after becoming aware of the historical and present-day exploitation that tends to occur during research with Indigenous communities, the team shifted their focus to be more reflective of the community's needs. It developed an innovative research contract in close consultation with community members and legal professionals that could be used as a tool for negotiating community rights in all future knowledge collaborations (Traynor 2017).

Similarly, to address the challenges of limited resources for climate change adaptation and disaster response, the Caribbean-based OCSDNet project developed a *knowledge broker artifact* to facilitate and mainstream a common vocabulary across Small Island Developing States to improve collaboration during disaster-management responses. Using a design science[15] approach, the team engaged with diverse stakeholders to negotiate the creation of an *artifact* that could be used to plan and streamline a coordinated disaster response efficiently. Similar to other case studies, the team suggested that beyond the complex debates associated with developing shared terminologies, a more important challenge was in negotiating the diverse institutional and social arrangements among collaborating stakeholders.

Beyond tools, four other projects used case studies to examine the application of an open science research framework to various development challenges. In Kenya, the team sought to understand how open science may be harmonized with commercialization practices that tend to prioritize personal and intellectual property. The Brazilian team applied an open science lens to a complex social situation in Ubatuba to examine whether open science can facilitate the achievement of sustainable development outcomes across a range of actors and activities. The Kenyan example revealed the complexities of sustaining and scaling up open science initiatives in academic and policy environments that have ongoing relationships with the private sector, as these partnerships tend to value the protection of data and forms of collaboration that offer value for money. In particular in many southern global contexts, financially constrained research institutions face enormous pressure to procure research funding, often through systems of intellectual property (IP) protection, including copyright and patenting, and must actively pursue partnerships with the private sector. At the same time, the team found that most Kenyan institutions also use (where possible) open access tools such as repositories. These issues highlight the fact that institutional environments must be willing to embrace both open and closed systems of knowledge production.

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In the Ubatuba case in Brazil, the team raised the fundamental question of development—*for whom?*—when determining to what extent open science can support sustainable development. The team looked at environmental conservation issues in Ubatuba by engaging stakeholders from diverse sectors, including policymakers, members of the private sector, community groups, and academics. The authors suggest that while open and collaborative science does create new spaces and methods for traditionally marginalized groups to engage in scientific discussions and local problem-solving, these spaces may be limited by top-down management cultures, particularly within policymaking contexts. Participatory management is key to allowing the communication of complex scientific ideas and for diverse audiences to engage in the creation of new, socially relevant scientific data.

The OCSDNet team based at the National Scientific and Technical Research Council (Spanish: *Consejo Nacional de Investigaciones Científicas y Técnicas*, CONICET) in Argentina selected four case studies in Latin America to explore the degree and varying outcomes of collaborative knowledge creation and knowledge use. In particular, the team sought to inquire whether the practice and intention of open science could be used to achieve social needs, particularly in the case of neglected socioscientific topics that are important to local communities but may not be viewed as worthy of investigation by mainstream knowledge makers (e.g., pharmaceutical companies) due to their low profit potential. Through their analysis, the team identified that drivers (i.e., the individuals or groups initially engaged in mobilizing scientific knowledge for particular outcomes) are the key to gauging the anticipated degree of openness within processes of knowledge production. For instance, in a case study examining research on Chagas disease (an understudied tropical disease that affects poor communities), the team identified traditional scientists as the primary drivers of knowledge creation. In turn, a case study on the Jáchal-Veladero mining controversy revealed citizen activists and community groups as the main producers and distributors of knowledge.

In the first instance, the degree of openness (in the sense of equitable distribution of, access to, and creation of relevant knowledge) was primarily limited to scientific experts in molecular biology. Even when the scientific publications and the genetic information about Chagas were made open, a high degree of technical competency was required in order to access the information and translate it into usable knowledge. In the case of the Jáchal-Veladero dispute, a more horizontal flow of knowledge and communication around the environmental pollution problem was possible because the primary driver of knowledge use was a coalition of local miners and community organizations who wanted the mine to be closed to stop cyanide leaching. In this case,

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they actively worked with experts who translated the technical reports into accessible knowledge so that citizens could use them for advocacy purposes.

Two other case studies were conducted by this Argentinian team. One involved conservation of the endangered jaguar in Argentina, and the other involved studies of migrant population in Mexico. In the conservation case, citizens were easily attracted to support such studies as data collectors as biodiversity efforts are relatively free from social conflict. In this case, both the citizen scientists and researchers see the jaguar as the benefactor of the knowledge being produced to address a local problem. Thus, there was no dispute over which knowledge mattered more. Further, in the case of the study of migrant issues in Mexico, the social scientists have to balance a number of delicate social political issues, as well as how migrants see their own positions and what they identified as challenges. As a result, the researchers were more reluctant to make their knowledge open.

These four case studies illustrate that the degree of openness of knowledge produced from research depends on the kinds of research being performed, who drives the research agenda, and, importantly, for whom the research is being performed. Thus, openness is situated and highly conditioned by the conditions of knowledge production.

Finally, using a network-building and advocacy approach with the assistance of social media tools, surveys, and workshops, another OCSDNet research team (Project SOHA) sought to define and promote open science and open access across a number of universities in French-speaking West Africa and Haiti. Considering the lack of access to academic journals experienced by many institutions within these regions, the team engaged university students and staff in discussions about access to research and the lack of representation of southern global (particularly French-speaking African and Haitian) researchers in the production of scientific knowledge. This group in particular engaged the idea of cognitive justice within the network—to challenge the colonial and neocolonial practices of erasure of local knowledge, and to advocate for the right of local citizens to participate in the creation of knowledge that is relevant to their own lives, experiences, and worldviews.

As a result of the extensive social network created across West Africa and Haiti, we have witnessed the emergence of several dynamic early-career researchers who have become local advocates of change within their respective countries and institutions. They have leveraged the importance of cognitive justice for Southern researchers and for *fair* open science within many international speaking forums. The project team also emphasized the importance of self-autonomy through do-it-yourself publishing and employing the methodologies of the open science hardware movement as a means for

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creating sustainable local development. Unlike other projects within the network, this action-oriented initiative is continually building its foundation and methodologies. What the project demonstrated is that shared values, through a commitment to claiming cognitive justice, is a precondition to local knowledge-making.

In this sense, the SOHA project is consistent with the first examples on the development of tools in South Africa and the Small Island Developing States, as they demonstrate that open science can be imagined as a loose ideology or mindset rather than a fixed set of practices or one-size-fits-all protocol. Imagining open science in this way allows flexibility in solving complex development challenges and issues. At the same time, this process of negotiation can be deeply complex and time consuming, particularly when working across heterogeneous communities with different sociocultural and institutional arrangements. By comparison, the Kenyan, Brazilian, and Argentinian case studies demonstrate the tensions that can emerge among various communities of knowledge actors, particularly those in pursuit of financial goals versus those concerned with social objectives. They highlight the importance of building partnerships across diverse sectors, with different actors involving complex negotiations that establish trust and defined roles for resource sharing to maximize the potential of open science in development.

Together, these six cases illustrate the power and complexity of multiactor collaborations, particularly in southern global contexts where independent institutions often lack sustained funding and resources but can nevertheless harness diverse skill sets to innovate. These projects provide grounded examples of how open science can be adapted and applied to promote new forms of collaboration, knowledge sharing, and innovation to be used to tackle a wide range of issues.

Cross-Cutting Lessons and Conclusions

Despite the diversity of these projects, an overlapping set of themes and conditions emerged across all or many of the projects. These themes highlight some important aspects to consider when implementing an inclusive open science agenda that aims to meet development goals.

First and foremost is the importance of *building a common language* among open science practitioners. As we have seen with the disaster management artifact in the Caribbean, the harmonization of open science and commercialization in Kenya, the virtual herbarium in Brazil, and the community conservation project in Colombia and Costa Rica, the engagement of diverse stakeholders in collaborative processes requires a deliberate and reflective process around shared principles and goals, to ensure that

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everyone is striving toward a common objective. Within the network, we found the creation of the *OCSDNet Manifesto*[16] was indispensable in this regard. The intense process of debate and cocreation has led to a shared set of values, the establishment of trust among members, and a common vocabulary through which to pursue and discuss network goals and objectives.

The second point is that *a contextual or situational framing of open science* is key to encouraging local buy-in and ownership of a project. As we have seen through the diversity of projects in the network, there is no one-size-fits-all approach to open science. It is, instead, a flexible concept that should be adapted to reflect local norms and realities. In this way, a contextual approach to open science is one that encourages the inclusion of diverse actors and ways of knowing and helps in the actualization of cognitive justice. For instance, the approach to openness in post-Soviet Kyrgyzstan (where democracy and collaboration are often viewed with suspicion) is quite different from the one employed in Brazil, where participatory spaces are built into the constitutional fabric of the country.

Third is the need to *be critical of the processes and the information to be shared* within the design and negotiation of open science architectures. Complete openness is not always feasible, nor is it desirable in all situations for historical or sociopolitical reasons or due to differing work priorities of diverse collaborators. Evidence of this was clearly demonstrated in the South African case, in which the team worked to safeguard the traditional knowledge of Indigenous communities; and in the Brazilian virtual herbarium project, which recognized that data providers should have a say in deciding which data are made openly accessible to the public. When contributors have no say in whether their data is made open or not, the result could be disempowering rather than empowering. This finding reinforces similar lessons drawn from openness activities in other domains (Smith and Reilly 2013).

Fourth is the *potential importance of an active civil society and pursuing open science goals that are relevant to larger populations*. For instance, the Ubatuba-Brazil team recognized the importance of community groups in terms of their intentional engagement with policymakers and the private sector to collaborate on development issues within the region, while the Argentinian team acknowledged the role of community activists as key drivers in the success of an antimining campaign in the region. While the involvement of civil society may not be a precursor for all open science objectives, it nonetheless has a key role to play in leveraging community issues and demanding knowledge resources and accountability from those in traditional positions of power.

The fifth point is that *understanding the feasibility of funding and timelines of that funding is critical to the success of larger, long-term open science projects*. Ambitious open

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science projects in southern global institutions have a vital role to play in providing the general public with knowledge and information that are useful for determining development priorities and local decision-making, but realistically, they are also constrained by lack of access to viable, long-term funding and resources. The project-based timelines of most funders make it difficult to plan and implement long-term, larger-scale open science initiatives that demand flexibility, reflection, and adaptation at all stages of the research cycle to tackle complex development challenges. Funding institutions interested in seeing a real impact around open science in development should take these considerations into account when defining their priorities and criteria for funding allotment.

The sixth point is that evidence from the network demonstrates the *value of collaboration across disciplines* for solving complex development challenges and practicing more inclusive forms of science. Our study suggests that the notion of open science has been underconceptualized and underproblematized. Hence, advocates and practitioners of open science must strive to work beyond their respective silos and explore relevant work that has been done in other domains. A considerable body of literature has been written since the 1970s about development, with lessons and best practices for facilitating inclusive and participatory processes of community engagement.[17] Likewise, gender and critical race theorists have produced highly relevant critiques of Western positivist science that must be taken into consideration for the development of a situated and inclusive open science (Haraway 2008; Harding 2006, 2015).

Seventh, and in a similar vein, there is a need for *increased interdisciplinary and cross-sector collaborative research, particularly between actors in the Global South*. As described throughout this chapter, collaboration, in a multitude of forms, is essential when combining open science and social needs. Whether this is at the local level, between teachers and students (as seen in Kyrgyzstan), among communities, government, and the private sector (as seen in Ubatuba, Brazil, and Kenya), or among different students from different institutions and regions (as seen in West Africa), collaboration allows the sharing of skills, ideas, and resources for tackling complex development issues over the long term. It can also generate the momentum and ownership needed to disrupt the institutional norms that limit the potential of open partnerships.

In summary, the OCSDNet teams recognize that open science has the potential to transform the foundational structures of knowledge creation in new and important ways. It offers spaces, tools, opportunities, and principles that facilitate opportunities for historically marginalized groups to participate in knowledge production. It also validates new and existing forms of local knowledge. For instance, the high participation rate of female schoolchildren and women in citizen science projects in Kyrgyzstan

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and Lebanon, and the strong engagement of Indigenous leaders in the South African climate change project both illustrated this potential. At the same time, powerful actors such as the oligarchic multinational science publishers (Larivière et al. 2015) continue to resist the idea of knowledge as a public good and to maintain the status quo of keeping knowledge as a commodity for consumption by elites (Fyfe et al. 2017). The anthropologist Paul Sillitoe (2007, 16) observed, "The idea is not that the small local knowledge stone should knock Goliath science over. … It is that we should create space for others' ideas. This is necessary not only because it should continue to add to global science's awesome fund of knowledge, but also because it might help us to manage this knowledge more effectively for the planet and humankind."

Positioning this conclusion more broadly, the United Nations (UN) Sustainable Development Goal number nine recognizes the need to "build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation" (UN 2016, 11). In this regard, effective, inclusive open science has a key role to play in ensuring that infrastructure and innovation are locally appropriate, inclusive, and hence sustainable in the longer term. This calls for local participation and dialogue at all levels, including resources and policies from the top that must be grounded in and designed with knowledge from local communities. It is only through the inclusion and consideration of diverse human actors and experiences that open science might offer the opportunity for transformational human development.

Notes

1. See, for example, this widely accessed website: European Union (n.d.).

2. See https://ihub.co.ke/.

3. Visit www.ocsdnet.org for full project descriptions.

4. This framework was developed over several decades of work on natural resource commons and their governance.

5. We did this by including the questions in monthly and annual report templates, semistructured interview questions, and general group discussions throughout the funding duration of the network.

6. A Google Group is a closed, online forum that allows written discussion on a variety of topics.

7. The OCSDNet Research Coordination team, consisting of five members in five countries around the world, also participated in similar processes of reflection and discussion around their own observations of and contributions to power dynamics within the network.

8. See Albornoz et al. (2017) for ELPUB and for more information about the manifesto creation process.

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9. For a description of *buen vivir*, see Monni and Pallottino (2015).

10. For more information, see the annotated bibliography and reading list that we consulted (https://docs.google.com/document/d/10g0U2_aNsOWCSNulfsw3Ea0TEhbx18JoCL8I7a8QLZ8/edit).

11. The most common conception of a citizen scientist is as an individual who voluntarily spends time contributing to the crowdsourcing of data (often using online tools and infrastructure) as part of a larger research investigation with predefined questions and objectives. See chapter 14 of this volume for more on crowdsourcing in development. For instance, Silvertown (2009, 467) refers to a citizen scientist as "a volunteer who collects and/or processes data as part of a scientific enquiry," while Cohn (2008, 193) defines them as "volunteers who participate as field assistants in scientific studies."

12. PAR methodologies were originally conceived by development practitioners in the 1970s. These methods have been touted for their ability to uncover highly nuanced and locally relevant data, as well as their potential to achieve more sustainable outcomes, as they tend to focus on social transformation or citizen empowerment as concurrent research objectives (Chambers 1994; Hall 1992).

13. *Model Forests* are "social, inclusive, and participatory processes that seek the sustainable development of a territory and thus contribute to global targets related to poverty, climate change, desertification and sustainable development." See http://www.bosquesmodelo.net/en/bosques-modelo/ for more information.

14. Similar findings have been presented by the Research on Open Educational Resources for Development (ROER4D) Network, under a discussion of the tensions around operational openness within research processes; for further information, see King et al. (2016).

15. In the field of information systems, design science is a research paradigm that seeks to "extend the boundaries of human and organizational capabilities by creating new and innovative artifacts" (Hevner et al. 2004, 75).

16. The *OCSDNet Manifesto* is available in English, Spanish, French, and Afrikaans and can be accessed at https://ocsdnet.org/manifesto/open-science-manifesto/. See also Albornoz et al. (2017).

17. For example, see Chambers (1994) and Hall and Tandon (2017b).

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