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Expanding Perspectives on Open Science: Communities, Cultures and Diversity in Concepts and Practices
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Framing a Situated and Inclusive Open Science: Emerging Lessons from the Open and Collaborative Science in Development Network

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Abstract. What is open science and under what conditions could it contribute towards addressing persistent development challenges? How could we re-imagine and enrich open science so that it is inclusive of local realities and a diversity of knowledge traditions? These are some of the questions that the Open and Collaborative Science in Development Network (OCSDNet) is attempting to answer. In this paper, we provide the rationale and principles underlying OCSDnet, the conceptual and methodological frameworks guiding the research, and preliminary findings from the network's twelve globally diverse research projects. Instead of a "one-size-fits-all" approach to open science, our findings suggest that it is important to take into account the local dynamics and power structures that affect the ways in which individuals tend to collaborate (or not) within particular contexts. Despite the on-going resistance of powerful actors towards new forms of creating and sharing diverse knowledge, concluding evidence from the twelve research teams suggests that open science does indeed have an important role to play in facilitating inclusive collaboration and transformatory possibilities for development.

1. 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 [1]. A common conception of open science is the opening of the entire research cycle - from designing the question and methods, to collecting and analysing data, through to the communication and dissemination of findings [2] [3]. In principle, these concepts collectively strive for an environment that facilitates opportunities to participate in knowledge production and circulation for people who have been historically excluded. As such, the growing momentum around open science provides a key opportunity to reflect on and reimagine the ways in which we

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understand and conduct science, and how knowledge-making could be made fairer and more inclusive of diverse ways of knowing.

To date, however, the majority of action and discussion on open science has been dominated by Western actors and institutions, with a tendency to focus on the tools, infrastructure and cost models of producing knowledge 'openly' [4] [5] [6], with less focus on the underlying power structures that tend to determine who is or is not able to participate in knowledge-production processes, and for what aims [7] [8] [9] [10] [11].

The Open and Collaborative Science in Development Network (OCSDNet) is an international research network, launched in 2015, to address the fundamental question of whether and how open science has the potential to contribute to the achievement of development goals and opportunities [12]. Funded by IDRC in Canada and DFID in the UK, with coordination support from Kenya's iHub[2] 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 from highly diverse disciplinary backgrounds, including law, 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 within distinctly different contexts, each team explored the challenges and opportunities for an open and collaborative science, and the potential of open science to facilitate fair and sustainable development.

OCSDNet recognises that throughout recent history, processes of knowledge production and dissemination have been shaped and solidified by a privileged and exclusive set of actors, ultimately influencing the way in which the world understands 'valid' and 'legitimate' scientific knowledge and research. This limited representation of knowledge leads to an incomplete understanding of the world and of the issues affecting local populations [10] [13]. Unchallenged, this system will continue to exacerbate knowledge and research inequalities, with serious consequences for sustainable and equitable development [14].

As the projects in the network will have reached their completion by June 2017, this paper provides a preliminary analysis of some of the key lessons that have shaped the ways in which OCSDNet members have come to re-imagine the potential of open science to transform processes of knowledge production and contribute to sustainable development. The paper will begin with a discussion of the network's background, including the methodologies that have guided research conducted between 2015 and 2017. This will be followed by an overview of the ways in which individual projects have contributed towards co-constructing a new and more nuanced understanding of open science.

Some projects have contributed towards refining open science at the 'grassroots' level of sustainable development through the implementation of small-scale citizen science projects at the community level. At the same time, others have contributed towards the reimagining of the field through a case-study analysis of existing, longer-term open science initiatives, including the sustainability challenges and social tensions that tend to arise as openness 'scales up' within or between institutions and their networks. Finally, other research teams have sought to apply network-defined open science principles within their unique contexts to develop new tools and frameworks

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

[3] See Annex 1 in this paper for a list of project names and keywords, or visit www.ocsdnet.org for full project descriptions

for understanding the potential of open science to contribute towards complex development and societal challenges.

Despite the diversity of projects within the network, many overlapping findings emerge, which demonstrate the importance of re-imagining open science in the context of complex development issues. Through the application of a contextualized or 'situated' approach towards defining and practicing open science, this paper concludes with the need to focus on making science more inclusive of a diverse set of actors and their epistemic traditions.

2. Network Background & Methodologies

The conceptual framework that informed the initial research questions for the network was based on the Institutional and Development Analysis (IDA) framework developed by Elinor Ostrom and colleagues over several decades of work on natural resource commons and their governance. Ostrom's work challenged the conventional wisdom around the need for government regulation of public resources (such as forests, fisheries, etc.) in order to attain sustainability and benefit sharing [15] [16].

In more recent years, this framework has also been applied to knowledge as a "commons," which cross-cuts national and disciplinary boundaries [17] [18]. Taking into account the unique attributes of knowledge and information that are distinct from natural resources, Frischmann, Madison and Strandburg [19] modified the IAD framework into a "Knowledge Commons framework" to aid other researchers with empirical research on different forms of commons. The framework provides a number of guiding research questions around the nature of the community in question, the kind of the resources in use, the existing institutional arrangements, and the interactions that take place within the community. Within OCSDNet, these questions were used and adapted to structure our data collection activities with the sub-projects, by including them in monthly and annual report templates, semi-structured interview questions and general group discussions throughout the network's duration.

While using this framework as a guideline for collecting data from research teams, observations around team and network working dynamics were also drawn from exchanges within a closed Google Group established for network communication, as well as offline network dialogues, social media discussions (e.g. Facebook groups and Twitter) and formal academic communications - including publications and conference presentations. Project teams were encouraged to share events, resources and best practices as part of the field and network-building exercises. It should be noted here that the OCSDNet Research Coordination team (consisting of five members positioned variably in five countries around the world) also participated in similar processes of reflection and discussion, around their own perpetuation of power dynamics within the network.

Along with these more traditional data collection activities, OCSDNet explored the potential of participatory, consensus-building exercises through the design of an "OCSDNet Manifesto" - a document that has attempted to consolidate the shared understanding of what Open and Collaborative Science offers to scientific research and development.[4] These discussions and the seven consequent "open science principles" that were developed, have had a substantial effect on the way in which many projects

[4] see Albornoz et. al, [21] for ELPUB for more information about the manifesto creation process

have assessed their own findings and ways of working.

The various mixed methods described above, guided by an iterative process of reflection towards our original conceptual framework, has generated a large volume of qualitative data and media artifacts. Much of this data has been analysed iteratively, over the course of the network's duration, but the final analysis continues to take place through qualitative-data coding processes to uncover themes and ideas that allow for greater comparison between diverse and complex projects.

The next section will discuss some of the key, preliminary findings that have emerged from the twelve individual research projects, with the intention of presenting a framing of open science that extends beyond a discussion of the 'tools' and 'cost models' associated with working openly. Instead, all cases look at the innovative ways in which OS principles can be applied to complex development questions and scenarios, with a focus on the socio-cultural contexts that have the potential to enable or curtail the potential for open science as an effective tool for achieving sustainable development objectives.

3. Emerging Lessons from OCSDNet Projects

An advantage afforded by the diversity of project membership and contexts is we are afforded the opportunity to interrogate the manifestation of open science practices at varying scales, from the grassroots, to the institutional, regional and national levels. With this in mind, we have grouped the projects into three thematic categories for analysis:

1) Practicing OS at the 'Grassroots;' *(4 projects)*
2) Analysing existing OS projects in the context of development *(2 projects)*; and
3) Exploring the potential of Open and Collaborative Science through new Tools and Frameworks *(6 projects)*

The complex discussions that OCSDNet members have had around defining 'development,' are beyond the scope of this paper. However, it should be noted that network members have broadly agreed on a notion of development that encapsulates Appadurai's "Right to Research," [20] which acknowledges that all humans have the capacity to aspire towards imagining their own knowledge and futures. Appadurai's work echoes Amartya Sen's Human Capabilities Approach, which posits human development as 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,'' as expressed in terms of one's agency to exercise ''choices'' [22]. The purpose 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 be healthy, to be knowledgeable by taking part in knowledge making, and to actively participate in community life. In this regard, the Latin American concept of *buen vivir*[5] ("the good living") has also informed the network's conceptual framework, as has the ancient African concept of *Ubuntu* - a philosophy that celebrates the strength of humans working and living in community with one another [23]. Taken together, these concepts comprise a framework of development that positions human beings as agents, working towards common goals,

[5] For a description of *buen vivir*, see [26]

and using the tools and forms of knowledge that are most relevant to their unique socio-cultural contexts[6].

3.1. Practicing Open Science at the 'Grassroots'

"Grassroots" development, well-known since the 1990's, refers to development research and activities that tend to focus on the community or micro-level context. The intention of this approach is to facilitate and pursue a 'bottom-up' approach to development, in which ordinary people are directly involved within activities meant to improve their lives [24]. This approach arose largely due to the growing opposition against 'top-down,' macro-development strategies that tended to dominate development discourse and practice during the 1980's. In particular, these macro-level approaches tended to dismiss local contexts and prevailing power structures, and hence failed to procure anticipated outcomes [25].

We borrow the notion of 'grassroots' development here due to its similarities to the localized and small-scale citizen science-initiatives that are present in four OCSDNet projects. These projects allow for a deeper understanding around the possibilities of initiating, managing and assessing small-scale open science initiatives that demand minimal funding, and which can be initiated, planned and completed in a relatively short time frame. They likewise 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 importantly, they provide the opportunity to assess whether a small-scale open science project-approach can have positive implications for sustainable community development.

Table 1. Practicing Open Science at the 'Grassroots'

Project Name	*Key Words*
Water Quality and Social Transformation in rural Kyrgyzstan	Kyrgyzstan, rural communities, citizen science, environmental conservation, water quality, participatory action research, open science motivation, teachers and students
Community-driven environmental conservation in Costa Rica and Colombia	Costa Rica, Colombia, participatory action research, citizen science, Model Forests, human capabilities, adaptive capacity, sustainable development, biodiversity
Water quality and community velopment in Lebanon	Lebanon, Citizen science, participatory research, community-based environmental management, water quality, empowering conservation, bottom-up policy making
Open Science Hardware for Development in Southeast Asia	SEast Asia, open science hardware (OSH), transnational networks, little science, citizen science, do it yourself (DIY), Indonesia, Thailand, Nepal, tools, participation, tinkering, Right to Science

In reference to *Table 1*, all four grassroots open science projects position the concept of 'citizen science,' as central to their methodologies and conceptual

[6] As our conceptual framework draws heavily from a diversity of thinkers from different fields, we have put together an annotated bibliography and reading list to allow interested readers to go deeper into the literature that we consulted:
https://docs.google.com/document/d/10g0U2_aNsOWCSNulfsw3Ea0TEhbx18JoCL8I7a8QLZ8/edit

framework. In general, 'citizen science' is a broad term that has come to convey an array of meanings and actions, depending on the context. Perhaps the most common conception of a 'citizen scientist,' is an individual who voluntarily spends time contributing towards the crowd-sourcing of data (often using online tools and infrastructure) as part of a larger research investigation with predefined questions and objectives. For instance, Silvertown [27] refers to a citizen scientist as "a volunteer who collects and/or processes data as part of a scientific enquiry;" while Cohn [28] defines them as "volunteers who participate as field assistants in scientific studies." While these forms of citizen science may indeed have important outcomes for knowledge production and development, there tends to be less focus on the individual as a local expert, or co-researcher, who is able to have input in the design of the research process, questions and data analysis.

Three of the four teams listed above have positioned *transformation* and/or *empowerment* as key objectives within their projects. On the one hand, while citizens are involved, in various ways, within processes of data collection, they also have the opportunity to participate in the identification of key local challenges, and perhaps to provide input on how and where data is collected, as well as any consequent actions that should be taken once information is collected and assessed.

In Kyrgyzstan, the OCSDNet research team worked with rurally-located school teachers and students to design an experiment to test local water quality, after the communities acknowledged that water pollution is a significant issue within the area. This was by no means simply an act of "designing and rolling out" an experiment, but instead involved complex discussions with teachers, students and research organisations that focused on *who* should be able to participate in scientific knowledge production and for what purposes. Throughout the duration of the project, teachers and students began to re-define their ideas of who a "scientist" is, and what scientific research could entail. Similar findings were encountered by the research team in Lebanon, who recruited a group of local volunteers (all of whom happened to be women), to conduct water-quality testing in fifty rural villages. In the end, not only were citizen scientists feeling more informed about water issues in their respective areas, but felt empowered, through their acquired knowledge, to begin making demands on government to pay attention to water-quality issues that affect entire communities.

Both of these projects highlight instances where, given the opportunity to participate in processes of creating and analysing locally relevant knowledge, communities who are (to varying extents) 'marginalised,' can use their knowledge not only to address a pertinent local challenge, but also to alter the way that they feel about themselves, as active and informed citizens within their respective communities. In particular, given the notable voluntary participation from women (in Lebanon) and female school children (in Kyrgyzstan), our research may suggest that a local, exploratory approach to open science could have implications for increasing the representation of women and girls within scientific initiatives.

In the cases of two projects in Costa Rica/Colombia and South East Asia, citizen science was explored and negotiated in different ways. In the Latin American case, the team sought to bring together local community members and academic researchers to discuss and negotiate how the "Model Forest" approach to sustainable development may be adapted and negotiated in the context of open science. While the project did not employ the collection of formal, quantitative data, the input from both parties was used to observe opportunities for collaboration and knowledge-sharing towards achieving

local development goals. In the end, seven locally-driven open science initiatives were devised around the theme of local environmental adaptation - including a farming agroecology network, rainwater harvesting, a tree nursery and ecotourism awareness.

On the other hand, within the South-East Asian project, a much more subtle version of citizen science was seen to facilitate and assess project activities, through what the team refers to as '*a small science.*' Through this approach, science (and particularly the design of new tools and hardware) was envisioned as a gently facilitated process of creative engagement between diverse participants (including artists, designers, students, teachers, etc.), oftentimes without a tangible social or development objective in mind. The idea was that through bringing diverse individuals into a shared, physical space and with access to a wide range of tools and materials, there could be the potential to stir and foster creative innovation beyond the scope of an intricately planned workshop agenda.

These four projects highlight the deep nuances of characterizing '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 constitutes a 'citizen scientist,' 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 the power to create relevant, local knowledge. To varying degrees, all four of these OCSDNet projects were designed to provide increased power and opportunities for regular citizens to participate in processes of knowledge creation and discussions that could have implications for development challenges 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 of these projects position citizens as agents of change with important, pre-existing expertise, rather than merely as volunteers involved in data collection for a pre-established project agenda.

3.2. Analysing Existing Open Science Projects

Along with developing an 'on-the-ground' perspective of grassroots open science initiatives discussed above, two projects within OCSDNet sought to examine, at a meta-level, the challenges and opportunities for larger, complex and ongoing open science initiatives that extend beyond the two-to-three year funding scope of the network. These projects assist in extending the perspective of the network towards a more objective 'outsider' perspective regarding the complexities of initiating, sustaining and scaling-up open science practices in the longer term. Given that open science is a relatively new field that continues to be defined and taken-up in different ways and in different contexts, these projects provide valuable insight regarding the complexities and longer-term 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 goals.

Table 2. Analysing Existing Open Science Projects

Project Name	*Key Words*
Evaluating Open science e-infrastructure in Brazil	Brazil, virtual herbarium, botany, interdisciplinary collaboration, e-database, open science infrastructure
Negotiating Open Science in Argentina	open science, Argentina, negotiating openness, opening process, boundary objects

In the Brazilian case study highlighted in *Table 2*, the OCSDNet research team sought to understand how diverse users were accessing a Brazilian-based open access e-database and for what purposes; as well as documenting any benefits to data providers themselves. 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 centralised 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 to 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 datasets and more than 1.4 million images [29].

The OCSDNet research team encountered impressive results around the usage of herbarium records, documenting not only the surprising frequency with which data is accessed and used (1.7 *billion* records accessed between 2012 and 2017), but also the diversity of the users, who ranged from Masters and PhD students, to government representatives, local research organisations, NGO workers, the private sector, and younger students. Importantly, 94% of users were residents from Brazil, highlighting the immense importance of providing access to local knowledge through accessible, online tools and in local languages.

Perhaps most surprising for the team, however, was around the complex negotiations and cultural shifts that needed to occur, throughout the years, to ensure the project's success. For instance, while preliminary requirements for data providers demanded complete openness, through a series of negotiations, the parameters have since changed to allow data providers the flexibility to decide, on their end, which records are made openly available and how. On the other hand, all decisions regarding the technological aspects of the network's architecture and e-infrastructure are left to the technologists. Thus, in this case, it was important for key actors to have some degree of power regarding their contributions towards maintaining the herbarium; while simultaneously having appropriately defined roles to allow for 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 amongst all actors.

In an Argentinean study, the team chose to assess four locally initiated open science case studies encompassing a broad range of disciplines, namely: the New Argentinean Virtual Observatory - NOVA (*astronomy*); Argentinean 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. The team was particularly interested in understanding the consequences of 'scaling up' open initiatives, noting that while some institutional models of open science do exist, there is less emphasis on the initiation of openness at a 'laboratory level,' and how the transition from the laboratory to institutional level occurs in practice.

Through their analysis, the Argentinian team noted that while the four case studies employed different methodologies and actors for the collection of data, all had the overlapping consequence of making collected data more accessible to the general public. Furthermore, their findings suggest that as each open science initiative progressed to encompass different aspects of the research cycle (project planning to data collection to analysis to dissemination, etc.), there was a need to reflect on and reconsider the tools, resources and infrastructure required for each new phase. From a sociocultural perspective, this process of transition puts new strains on open science practitioners, as each new phase may entail a new form of contradiction and hence negotiation with traditional institutional norms and structures.

Looking at both the Brazilian and Argentinian case studies, several key lessons emerge regarding the complexities of sustainable, longer-term open science initiatives. First and foremost, open science is not merely the design of new "tools" that can allow for easier collaboration between individuals. Instead, an effective open science demands complex negotiations around roles and responsibilities; principles and priorities; timelines and resources. It may require new and innovative thinking at each stage of the research cycle and a reflection on how such practices may coincide with existing cultural and institutional norms. From a practical perspective, large-scale initiatives also imply 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,' since the sustainability of future funding is by no means a guarantee [29].

From a development perspective, large, longer-term open science projects have an important role to play in providing the general public with knowledge and information that is useful for informing local decision making and determining development priorities. However, at the same time, due to a lack of access to viable, long-term funding and resources experienced by many Southern institutions, feasibility and timelines are critical considerations and potential hurdles to the success of such initiatives. Given the "project-based" timeline of the majority of funders, it may be difficult to plan and implement long term and larger-scale open science initiatives that seek to tackle complex development challenges and that inherently demand flexibility, reflection and adaptation at all stages of the research cycle. Thus, funding institutions who are interested in seeing real impact around open science in development initiatives must take these considerations into account while defining their priorities and criteria for funding allotment.

3.3. Exploring the potential of Open and Collaborative Science through new Tools and Frameworks

Beyond the creation and analysis of open science initiatives, other OCSDNet teams have taken the perspective of the network a step further by imagining the potential of open science through a variety of new tools and frameworks. As mentioned earlier in this paper, over the course of the past two years, all members of the network have been actively involved in a participatory process of designing an 'open science manifesto,'

which presently consists of seven key principles that reflect the network's understanding and practice of open science, as a collective. Beyond the importance of this document for establishing trust and understanding between network members, it also provides a useful lens through which to consider localised development challenges, and whether an open science approach could be an effective way towards addressing such challenges. Importantly, the manifesto seeks to encourage plural forms of knowing and the collaboration of diverse actors across disciplines, languages and geographic boundaries.

In this regard, through the course of their research, two teams applied network principles of OS towards the creation of 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 the discourse and possibilities around OS for addressing particular local challenges.

Table 3. Exploring the potential of Open Science through new Tools and Frameworks

Project Name	*Key Words*
Researcher contracts for Indigenous knowledge in South Africa	South Africa, indigenous knowledge, climate change, intellectual property rights, research contract, decolonising research methodologies, terra nullius
Disaster Management Tools for Small Island States	Disaster recovery plans, Small Island Developing States, Design Science, regional collaboration, knowledge broker artifact
Commercialisation & Open Science in Kenya	Kenya, IP laws, open science, universities, private sector, collaboration, research partnerships, commercialisation
Sustainable development and the potential for OCS in Brazil	Ubatuba, social change, sustainable development, potential of open science, participatory action research, diverse actors
Social problems and the potential of OS in Latin America	Latin America, openness, non-hegemonic countries, social problems, collaborative science, cognitive exploitation
Building Open Science Social Networks in West Africa & Haiti	West Africa, Haiti, open science networks, science shops, open repository, open research, participatory research, cognitive justice

In the case of tools, an OCSDNet team in South Africa sought to employ the principles of open science to negotiate a community-researcher contract in order to safeguard the knowledge of indigenous communities around climate change and other topics. Originally, the team had planned their project agenda to understand what knowledge exists within indigenous communities in this regard, and hence what knowledge might be openly shared, to promote shared learning around adaptation to climate change. However, after becoming increasingly cognisant of the historical and present-day cognitive exploitation that tends to occur during research with indigenous communities, the team changed their focus to be more reflective of the community's needs. Thus, they set-out to develop an innovative research contract, developed 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 [30].

Similarly, in attempting to address the challenges of limited resources for climate change adaptation and disaster response, a Caribbean-based OCSDNet project developed a 'knowledge broker artifact,' to create and mainstream a common vocabulary across Small-Island Development States (SIDS) for improved collaboration

during disaster-management responses. Using a "design science" approach, the team engaged with diverse stakeholders to negotiate the creation of an "artifact," that could be used to efficiently plan and streamline a coordinated response. Similar to previous case studies, the team suggested that beyond the intricate debates associated with the development of shared terminologies, a more important challenge was in regards to negotiating the diverse institutional and social arrangements between collaborating stakeholders.

Both of these examples demonstrate that 'open science' can be imagined as a flexible philosophy or mindset, rather than a fixed set of practices. Imagining the concept in this way allows for increased flexibility in solving complex development challenges and issues, without relying on a one-size-fits-all protocol. However, at the same time, this process of negotiation can be deeply complex and time-consuming, particularly when working across heterogenous communities, with different socio-cultural or institutional arrangements.

Beyond tools, four other projects use a case-study approach to examine the potential of applying an open science research framework to various, complex development challenges. In Kenya, the team sought to understand how open science may be harmonised with commercialisation practices, which tend to prioritise IP protection and personal property, while the Brazilian team applied an open science lens towards a complex social situation in Ubatuba, seeking to examine whether OS can be applied to facilitate and achieve sustainable development outcomes across a broad range of actors and activities. The Kenyan example reveals the deep complexities of sustaining and scaling-up open science initiatives within academic and policy environments that have on-going relationships with the private sector, who tend to value the protection of data and collaboration that offers value-for-money. Particularly in many Southern contexts, financially constrained research institutions face enormous pressure to procure research funding, often through systems of IP protection, including copyright and patenting. On the other hand though, the team found that most Kenyan institutions make use of both open access tools (such as repositories) where possible, as well as pursuing partnerships with the private sector. In this way, an institutional environment must be flexible to both 'open' and 'closed' systems of knowledge production, but remains largely driven by external funding agendas and possibilities.

In the Ubatuba case study in Brazil, the team raises the fundamental question of 'development for *whom*?' in determining to what extent open science can be used as a tool for achieving sustainable development outcomes. Using participatory methodologies, the team looked at environmental conservation issues in Ubatuba Brazil, through engagement with stakeholders from diverse sectors. The authors suggest that while open and collaborative science does create new spaces and methods for traditionally marginalised groups to engage in scientific discussions and local problem-solving, the complexity of some development problems demands the strategic involvement of larger institutions.

Similarly, acknowledging the historic bias whereby the production and legitimisation of scientific knowledge has been dominated by the North, an OCSDNet team in Argentina draws on four diverse case studies throughout Latin America, in order to look critically at the roles and outcomes of collaborative knowledge creation through an open science lens. The project concludes by suggesting that different "types" of development challenges may be more or less amenable to collaborative practices of open science.

Thus, within a southern context, the Brazilian, Kenyan and Argentinian case

studies demonstrate the immense importance of building *partnerships* across diverse sectors and with different actors in order to maximise the potential of open science in development. While this involves complex negotiations and the establishment of trust and defined roles, it is necessary not only for understanding and addressing the complexity of some situations, but also from the perspective of project sustainability and resource sharing.

Finally, using a somewhat different approach, another OCSDNet research team sought to define and promote open science and open access in French-speaking West Africa and Haiti using a network-building and advocacy approach, through the assistance of social media tools, surveys and workshops. Acknowledging the lack of access to academic journals experienced by many institutions within the regions, the team engaged university students and staff in discussions about access to research and the proportional lack of representation of Southern (and particularly French-speaking African and Haitian) researchers in the production of scientific knowledge. This group also helped to promote the concept of 'cognitive justice' within the network - a concept which acknowledges the right of human beings to participate in the creation of knowledge that is relevant to their own lives, experiences and worldviews.

As a whole, these six projects represent the way in which open science, as a concept, can be adapted and applied to promote collaboration, knowledge sharing and innovation to tackle a wide range of development questions and issues. Particularly in Southern contexts, where independent institutions may lack access to funding and resources, these cases highlight the power and complexity of multi-actor collaborations in order to take advantage of diverse skillsets, limited resources and to find innovative solutions to complex development challenges.

4. Cross-Cutting Lessons & Conclusions

For the purposes of this paper, OCSDNet projects have been divided into three categories, with the intention of viewing open science 1) from the local, 'grassroots' level using an insider approach; 2) from a meta-level 'outsider' perspective to understand the challenges of scaling and sustaining larger open science projects; and 3) by practically and theoretically exploring the potential of open science principles through the creation of new tools and frameworks for addressing local development issues.

Despite the diversity of these projects, an overlapping set of themes and conditions emerged across all or many of the projects, which demonstrate some important aspects to consider when implementing an open science agenda that is inclusive, and which aims to meet development goals. First and foremost is the importance of *building a common language* amongst open science practitioners. As we have seen with the disaster management artifact in the Caribbean, the harmonisation of OS and commercialisation and OS in Kenya, the virtual herbarium in Brazil, and the community conservation project in Colombia and Costa Rica, the engagement of diverse stakeholders in processes of collaboration requires a deliberate and reflective process around shared principles and goals, to ensure that everyone is striving towards a common objective. Within OCSDNet, we have found that the creation of our OCSDNet manifesto was indispensable, in this regard, amongst our own membership.

Secondly, *a contextual or situational framing of open science is key f*or encouraging local buy in and ownership of a project. As we have seen through the

diversity of projects within the network, there is no one-size-fits-all approach to open science, but 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 hence cognitive justice.

A third theme to arise throughout our analysis is the need to *be critical of the processes and information to be shared* within the design and negotiation of open science architectures. Complete openness is not always feasible nor desirable in all situations for historical or socio-political reasons, or merely 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, as well as more practically within the Brazilian virtual herbarium project, which recognised that data providers should have a say in deciding what data is made openly accessible to the public. When research or data contributors have no say in whether their data is made open or not, the result could be a disempowering, rather than empowering one.

Another cross-cutting lesson to emerge from all projects is the importance of not 'remaking-the-wheel,' in the creation of discourse and practices around open science. Certainly in regards to smaller-scale citizen science initiatives, there is a considerable amount of development literature that has been written since the 1970's, with lessons and best practices for facilitating inclusive and participatory processes of community engagement, which position problem solving and social transformation as key objectives[7]. Gender and critical race theorists [31] [32] [33] have likewise produced invaluable work that must be taken into consideration for the development of a situated and inclusive open science. Thus, new advocates and practitioners of open science must not work in silos, but explore relevant work that has been done to provide the groundwork for an emerging way of conceptualising and practicing a more inclusive and collaborative science.

In a similar vein, there is a need for *increased interdisciplinary and cross-sector collaborative research, particularly between Southern actors.* As described throughout the paper, collaboration, in varying 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), between communities, government and the private sector (as seen in Ubatuba, Brazil), or between different students from different institutions and regions (as seen in the West African project), collaboration allows for the sharing of skills, ideas and resources for tackling complex development issues over the longer term, as well as generating the necessary momentum and ownership to work against institutional norms which could potentially limit the potential of 'open' partnerships.

In sum, OCSDNet teams have recognised that open science has the potential to transform the foundational structures of knowledge creation in new and important ways. In particular, open science has the potential to offer spaces, tools, opportunities and principles that facilitate opportunities for historically marginalised groups to participate in knowledge production, and to validate new and existing forms of local knowledge. At the same time though, there is a subsequent realisation that powerful actors continue to resist OS narratives that situate knowledge as a public good to which everyone should be able to access and contribute towards. However, as Sillitoe [13] explains:

"The idea is not that the small local knowledge stone should knock Goliath

[7] For example, see [35]

> 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."

To position this conclusion more broadly, Goal #9 of the Sustainable Development Goals recognises the need to "build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" [34]. In this regard, open science has a key role to play towards ensuring that infrastructure and innovation are locally appropriate, inclusive and hence sustainable in the longer term. This calls for local participation and inclusive dialogue at all levels, including resources and policies from the 'top,' which must be grounded in and designed by 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.

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Annex 1. OCSDNet Project Names & Keywords

Short Title	Key Words
Practicing Open Science at the 'Grassroots'	
Water Quality and Social Transformation in rural Kyrgyzstan	Kyrgyzstan, rural communities, citizen science, environmental conservation, water quality, participatory action research, open science motivation, teachers and students
Water quality and community development in Lebanon	Citizen science, participatory research, community-based environmental management, water quality, empowering conservation, bottom-up policy making
Community-driven environmental conservation in Costa Rica and Colombia	participatory action research, citizen science, Model Forests, Costa Rica, Colombia, human capabilities, adaptive capacity, sustainable development, biodiversity
Open Science Hardware for Development in Southeast Asia	open science hardware (OSH), transnational networks, little science, citizen science, do it yourself (DIY), Indonesia, Thailand, Nepal, tools, participation, tinkering, Right to Science
Analysing Existing Open Science Projects	
Evaluating Open science e-infrastructure in Brazil	Brazil, virtual herbarium, botany, interdisciplinary collaboration, e-database, open science infrastructure
Negotiating Open Science in Argentina	open science, Argentina, negotiating openness, opening process, boundary objects
Exploring the potential of Open and Collaborative Science through new Tools and Frameworks	
Researcher contracts for Indigenous knowledge in South Africa	South Africa, indigenous knowledge, climate change, intellectual property rights, research contract, decolonising research methodologies, terra nullius
Commercialisation & Open Science in Kenya	Kenya, IP laws, open science, universities, private sector, collaboration, research partnerships, commercialisation
Disaster Management Tools for Small Island States	Disaster recovery plans, Small Island Developing States, Design Science, regional collaboration, knowledge broker artifact
Sustainable development and the potential for OCS in Brazil	Ubatuba, social change, sustainable development, potential of open science, participatory action research, diverse actors
Social problems and the potential of OS in Latin America	Latin America, openness, non-hegemonic countries, social problems, collaborative science, cognitive exploitation
Building Open Science Social Networks in West Africa & Haiti	West Africa, Haiti, open science networks, science shops, open repository, open research, participatory research, cognitive justice