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Whose Infrastructure? Towards Inclusive and Collaborative Knowledge Infrastructures in Open Science

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Introduction

- 1 When one considers the concept of infrastructure, a generic image of bridges, sewers, water pipes and electricity cables tends to come to mind. These large, physical channels, tools and structures lay the groundwork required for many humans to live safe and efficient lives. When functioning as designed, infrastructures tend to be rendered invisible for most users (Star 1999). It is only when these physical entities break down that one tends to become cognizant of their contribution to daily life.
- 2 Between 2015 and 2018, the City of Cape Town experienced one of the worst droughts in recorded history, causing government officials to initiate massive water-usage restrictions to city residents and businesses. There were massive campaigns and speculation around when Day Zero would occur—the ominous future date in which all of the city’s usable water supplies would be depleted, should the necessary rain fail to return. Plans were made for the establishment of emergency distribution points, whereby all of the city’s four-million residents would be allocated a ration of 25-litres of water per day.
- 3 The threat of having no readily-available water for drinking, flushing toilets, bathing or cleaning was a shock to the wealthy (and predominantly white) Capetonians living in well-served and formal communities. What ensued was a political name-and-blame media discussion, whereby city officials were accused of incompetence and corruption for their presumed failure to upgrade the infrastructure necessary to avoid the disaster.

Wealthier residents began stock-piling bottled water, drilling private boreholes and purchasing large water tanks in an effort to harvest any rainwater for home usage. Swimming pools lay stagnant and many would-be tourists decided to alter their travel arrangements to avoid the inevitable fall-out of a city adjusting to no water. Amidst the chaos, the voices and lived experiences from Cape Town's many informal communities, often ignored in public discourse, began to emerge through various social media channels: "Poor black people have lived with no running water for many years but we've never seen any day zero campaigns" (Somebody 2018).

- 4 The Cape Town example highlights that while infrastructures might appear as seemingly neutral entities that provide the groundwork for human activities, a deeper analysis tends to reveal highly political nuances, with significant insight regarding divisions of power and privilege within a given context. In this case, while rich and middle-class residents enjoy the invisibility of (usually) well-functioning water-delivery infrastructures, for poor communities, this gap in service delivery is an everyday feature in their lives. In short, infrastructure (in this case, publicly funded infrastructure), does not serve all users equally.
- 5 Moving beyond discussions of physical nuts-and-bolts infrastructure, a similar critical analysis can be applied to existing knowledge infrastructures. In the field of open science, advocates have sought to "transform how we think about the collection, dissemination and value of data, the collaborative potential in science, and the public character of research" (Bezuidenhout *et al.* 2017). Action and discourse have tended to focus on the creation of new technological platforms and tools to facilitate sharing and reuse of digital information. There is an assumption that once these virtual infrastructures are in place, researchers and other collaborators will be able to participate in the creation of scientific knowledge in more equitable and efficient ways.
- 6 However, as the Cape Town example illustrates, it is shortsighted to assume that just because the invisible technical groundwork is in place for virtual collaboration, that users of this knowledge infrastructure will benefit equally from its installation. Instead, from a development perspective, this paper argues that it is necessary to reflect critically on who is being both included and excluded in the design and use of knowledge infrastructures. For the purposes of this paper, we use the term "inclusive knowledge infrastructures," defined as the tools, platforms, networks and other socio-technical mechanisms that deliberately allow for multiple forms of participation amongst a diverse set of actors, and which purposefully acknowledge and seek to redress power relations within a given context. While many virtual knowledge infrastructures have certainly assisted in facilitating collaborations through online spaces and mechanisms, there is less attention on the socio-political implications that transpire in terms of how and by whom such tools are used, and whose worldviews are being packaged and sold as most legitimate through these platforms.
- 7 Findings from the Open and Collaborative Science in Development Network (OCSDNet) demonstrate the importance of a critical reflection on inclusivity in the design and operationalization of knowledge infrastructures in order to foster opportunities for fair participation in scientific knowledge creation. Building on Safiya Umoja Noble's call for intersectional approaches to the study of the materiality of digital infrastructures (2016), this paper looks at three case studies generated by OCSDNet research teams between 2015 and 2017 which we believe highlight relevant aspects of what to consider in the design of inclusive knowledge infrastructures. The feminist concept of intersectionality, which

foregrounds awareness on the concurrent existence of racism, sexism and other forms of inequality, is important for those attempting to conceptualize the (re)development of more inclusive knowledge infrastructures.

Literature Review

- 8 In the field of development research and practice, there is often a tendency for funding agencies to push for more openness through technological research interventions, often for the sake of technology itself (Bezuidenhout 2017: 45). This type of technocratic “supply-side” thinking resembles critiques of the Information and Communication Technologies for Development (ICT4D) field (Krauss 2010), whereby advocates may assume that people will inherently benefit from new forms of technical infrastructure, rather than focusing on what diverse communities may be “demanding” from a development perspective (Chirumamilla and Pal 2013). Indeed, even at the global level of development institutions (such as the UN), ICTs continue to be treated as “apolitical tools for development” (Singh 2017: 7).
- 9 On the other hand, a growing number of scholars in the fields of anthropology, science and technology studies, informatics and development have begun to recognize the importance of critically reflecting on the role of knowledge infrastructures as often-invisible, but essential groundwork for human achievement and empowerment (Kenner 2014; Edwards *et al.* 2013; Star 2012; Kelty 2014). This section begins by outlining several examples of the ways in which different researchers have defined and designed knowledge infrastructures within their contexts and the role of these infrastructures in the project’s success (or failure) in the long run. The intention here is to demonstrate that “knowledge infrastructure” is a loose but important concept to consider in the design of research agendas that are more inclusive, equitable and meaningful to diverse actors. In what follows, we outline some of the growing literature related to knowledge infrastructures and intersectionality, and focus on several critiques of universality, as raised by feminist scholars of science investigating intersectional biases in digital technologies and platforms.

Knowledge Infrastructure Literature

- 10 Denisa Kera (2012) suggests that the emerging global movement around open hardware (in the form of technological tools, apps and hardware) has inspired an emergence of “geek diplomacy” whereby citizen scientists of both the North and South are inspired to create and share technical solutions to real-world challenges that are important to them. She argues that because of a focus on sharing within the movement, strong networks have emerged amongst and between Southern and Northern actors, with a side-effect being the creation of a critical-political body that is able to defy technical norms through “hacking.” In this case, the diversity of open hardware tools are both the products of citizen-scientist hackers, as well as the essential knowledge infrastructure that allow for networking, sharing and re-purposing between geographically diverse communities.
- 11 In a similar vein, Julia Elyachar (2010) has observed the mostly informal “communicative channels” (453) that exist amongst poor women in Cairo, which allow them to gain information regarding their communities and which contribute—in unobvious ways—to the economy and status of their families. The author suggests that these channels are an

important form of social infrastructure that are as vital for the city's economy as physical infrastructures like roads and bridges. At the same time, just as well-functioning physical infrastructure tends to be largely invisible to most users (Star 1999), women's labour and the communicative channels that they forge through time and effort tend to be overlooked within a capitalist economy that privileges more obvious income-generating activities typically undertaken by male members of a household (Elyachar 2010). Similar findings are echoed by Simone (2004), who noted the importance of "people as infrastructure" (407) in the context of resilience and survival for the poor in Johannesburg. In these cases, the concept of knowledge infrastructure can be applied to a construct that is neither physical nor technical but purely social. At the same time, social infrastructures (Neylon 2018) have many of the same qualities as other forms of infrastructure: they are mostly invisible, form the groundwork and networks for other key livelihood activities, and demand time and skill to create and maintain.

- 12 Beyond grounded examples of knowledge infrastructures from the field, other researchers have acknowledged the assumptions and restrictions that ultimately resulted in the creation of inaccessible and unusable knowledge infrastructures. For instance, in an interview, Chris Kelty (2014) relays a critique of an open education resource (OER) called *Connexions*:

"*Connexions* taught me that even if you build a really awesome technological system that completely blows your mind [...] it will mean nothing in a context where people are not looking for a mind-blowingly different way of creating what is essentially a textbook. If academics are content to write and teach in the way they always have, and if students are not really agitated about doing it differently, then there really isn't any way around that inertia. *Connexions*, like a lot of technological projects, was too proleptic and not diagnostic enough: it imagined a world in which all sorts of problems were solved: automated markup, easily transformed documents, remixability of content, a centralized repository of freely available teaching modules. But these weren't (and perhaps still aren't) the problems most teachers face."

- 13 Kelty's critique could also be applied to many examples of ICT4D¹ work, where a "solution" is proposed to a so-called "problem" that is in fact a problem perceived by technology designers rather than the technology users, highlighting the difference between demand-side versus supply-side development thinking.
- 14 Other scholars, recognizing the limits in current systems of knowledge sharing, have developed their own iterations, including the Platform for Experimental Collaborative Ethnography (PECE) (Fortun *et al. forthcoming*). PECE focuses on enabling online collaborative analysis, comparison, data re-use, and preliminary visualization. According to the design team, PECE is not only an investment in technical research infrastructure to support collaborative, experimental ethnography; it is also an experimental system in its own right, one designed to simultaneously conduct and query empirical humanities and creative social sciences. One of the ways it does this, for example, is by sustaining a running list of what is called substantive logics. In this case, diverse collaborators are encouraged to add their own "logics" (extending from their own experience and research), thus pluralizing and substantiating how a given project makes sense. PECE is just one example of new types of sociotechnical knowledge infrastructures that are being built and studied by researchers themselves with the aim of supporting knowledge pluralism. In a similar vein, recognizing the shortfalls of many MOOCs², which tend to systematize a rather one-sided form of knowledge replication and learning, Jacque

Wernimont from *FamTechNet* employed feminist theories to develop Distributed Open and Collaborative Courses that recognize the complexities of learning situations by collectively designing local platforms (Brown et al. 2016).

- 15 Finally, the importance of being cognizant of the larger landscape of policy and discourse analyses of policy within discussions of knowledge infrastructures should not be understated. In order to see changes in the way that knowledge infrastructures are conceptualized and built, these changes need to be embedded in policy discourse early on. Albornoz *et al.* (*forthcoming*) suggest that there is currently an over-representation of business and industry actors at the policy level who push for the integration of privately owned infrastructures, tools and services into scientific systems. These interests, and the consequent tools that are created, tend to develop new forms of exclusion, which have a particular effect on knowledge producers at the grassroots, who do not have access to resources and training to use them. If more equitable and inclusive infrastructures are to be built, the current consolidations of power and profits by business and industry actors within scholarly infrastructures must be closely tracked (Chen and Posada *forthcoming*).

Feminism, Open Science and Intersectional Technologies

- 16 Scholars working on questions of race, class, and gender have long argued that the margins can be sites of oppression and resistance, where subordinated groups and individuals can cultivate reflexive perspectives (Collins 1986, 2000; Crenshaw 1991; Fanon 1963; Hooks 1984). Rooted in Black Feminist Theory and Critical Race Theory, the notion of “intersectionality” was first introduced by legal scholar Kimberle Crenshaw in her seminal essay published in the late 1980s. The theory has since been taken up widely across disciplines and diverse cases (Carbado *et al.* 2014) including analyzing how bilingual youth navigate multiple inequalities when they translate for their immigrant parents (Kwon 2015), studying how the European Union handles multiple inequalities at the structural level (Verloo 2006), and understanding the experiences of underexplored identities in U.S. higher education (Mitchell *et al.* 2014).
- 17 In developing “intersectionality,” Crenshaw was responding to the tendency within identity politics to overlook or silence intra-group differences, a dynamic repeated throughout anti-racist and feminist movements to the detriment of black women. Focused on both the structural and political aspects of intersectionality with regards to rape and domestic abuse, Crenshaw highlighted the importance of engaging with issues like violence against women of color through an intersectional lens.
- 18 Leveraging concepts such as intersectionality, over the past three decades, feminist scholars have also been raising important critiques of science, debunking notions of objectivity and universality and emphasizing their social construction (Knorr-Cetina 1981; Harding 1986, 1991 2015; Haraway 1991, 1994). Feminist scholars of science have made critical interventions in revealing the construction of race/sex/gender/sexuality differences—and their historical variations—in modern Western sciences, especially the life sciences and medicine (e.g. Lock 1997; Schiebinger 1999; Fausto-Sterling 1992; Martin 1991; Terry 1999). For example, Madeline Akrich (1995) pushed forward understandings of how innovators, designers and promoters of technical devices constructed representations of their users and how, by inscribing those representations in the technical and organizational choices that they make, technology creators framed the boundaries of possible relations between users and devices. Such work on the history and

social construction of technology has been extended more recently to look at digital technologies and platforms, emphasizing the inbuilt assumptions and ideologies in seemingly neutral digital technologies (e.g. Hicks 2017; Noble 2018; Eubanks 2018).

- 19 This latest generation of feminist science scholars has been working to complicate dominant, neoliberal discourses about digital technologies as tools for social empowerment. By redirecting attention to the multiple strands of less-visible realities, these scholars have begun to highlight the ways in which science and technology are imbricated in circuits of state power and global inequality. We seek to extend this work to the growing scholarship and policy discussions surrounding Open Science which overlaps with but is not limited to movements advocating for Open Access and Open Data. While networked technologies hold great potential to enable more egalitarian processes of knowledge making, Watson-Verran and Turnbull's findings from more than twenty years ago remain relevant today: "Western contemporary technosciences, rather than being taken as definitional of knowledge, rationality, or objectivity, should be treated as varieties of knowledge systems" (1995: 116).
- 20 In other words, if knowledge infrastructures are to be (re)designed for greater inclusivity, then a key first step is to build on the decades of work produced by feminist scholars of science and to recognize the asymmetries of power and contexts out of which Open Science is emerging. We are keen to direct attention, as Noble (2016) and others have done, to the contradictions apparent in neoliberal discourse of openness as a tool for social empowerment in order to encourage greater dialogue about how we may be able to counter and recapture the concept through grounded practices.
- 21 Building on this scholarship, this paper seeks to investigate how knowledge infrastructures (many of which are assumed to be neutral or apolitical) may in fact replicate and reinforce the gendered, raced and other socio-political imbalances that exist within existing systems of knowledge production.³ In this paper, we offer three specific cases of knowledge infrastructures from the global South that broaden our understanding of the concept and explore the mutual co-constitution between social and material infrastructures. The subsequent analysis in this paper highlights that knowledge infrastructures encompass more than just technical tools and apolitical hardware. Indeed, knowledge infrastructures should be recognised as contributing towards the configuring of power relations and possibly holding opportunity for enabling diverse communities to become involved in knowledge-creation processes.

Methodology

- 22 The Open and Collaborative Science in Development Network (OCSDNet) was an international research network run from 2014–2017 that sought to address the fundamental question of whether and how open science has the potential to contribute to the achievement of development goals and opportunities. The network was composed of twelve international research teams throughout Latin America, Africa, the Middle East and Asia, and from highly diverse disciplinary backgrounds. Over the course of two years, 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 2017).

23 In this paper, the OCSD Network Coordination team draws on data generated by and collected about the twelve projects. As part of the meta-analysis for the network, research teams were asked to regularly reflect on their original research questions and approaches, and to assess whether and why their research was progressing as expected or not. As the Network Coordinators, we challenged them to reflect on the barriers or resistance they encountered and how/whether they sought to overcome any challenges. In addition, the projects also submitted detailed technical reports at the end of years one and two. Each project produced a variety of blog posts to share emerging learnings within the network and beyond. The meta-analysis of these materials, conducted by the OCSDNet coordination team, included two rounds of coding and analysis amongst team members in Peru, Colombia, Canada, South Africa and the United States. The first round of analysis entailed the coding of project-specific documents, while the second round included an analysis of insights gained across projects. See Chan *et al.* (*forthcoming*) for further details on the methodology.

Conceptual Framing: An Intersectional Approach to Knowledge Infrastructures

- 24 While feminist theory and practice has been widely influential in many disciplines over the past three decades, this work has had little noticeable uptake to date within the growing field of Open Science. In this paper, we leverage the sensitivities to power, relationality, intersectionality and context provided by this work in order to explore how we might begin to analyze and understand very different situations and practices with regards to open science in diverse contexts of the global South. The following section outlines three case studies drawn from the work of OCSDNet research teams. These cases were selected from amongst the twelve projects as they are best able to illustrate the types of diverse expressions of sociotechnical infrastructures that appear necessary to lay the groundwork for fruitful, just knowledge production. We draw out similarities and differences in how various actors chose to negotiate their respective scientific research processes under a paradigm of “openness.”
- 25 As noted by Edwards *et al.* (2013: 5), infrastructures are not “systems [with] end-to-end processes,” but rather “ecologies or complex adaptive systems,” in which a process of continuous learning and adaptation is (not always successfully) occurring. This imagining of infrastructure is particularly useful in the case of knowledge infrastructures, in the context of modern technology and networked collaboration. We suggest that the three cases illustrated in this paper demonstrate the importance of moving beyond a definition of infrastructure as merely a technical or physical entity and demonstrate how broader understandings of knowledge infrastructures may enable more sustainable and nuanced forms of collaboration and participation. The concept of intersectionality provides an important framework for assessing opportunities to imagine and realise knowledge infrastructures that are responsive to and inclusive of a diverse range of actors.
- 26 It is important to note that we offer these cases not as model templates of what we are calling “inclusive knowledge infrastructures” per se, rather, we include them in order to highlight how the Open Science community needs to think more contextually about diverse local needs and actors in order to develop more inclusive infrastructures.

- 27 The following table summarizes each case's contributions towards our understanding of the various points which policy makers, institutions and practitioners working on Open Science should take into account in the design and development of infrastructures for knowledge production and sharing.

Table 1: Summary of three OCSDNet knowledge infrastructure case studies

Project Name	Inclusive Infrastructure	Key Actors	Why was an intersectional approach important?
Knowledge Broker for Disaster Management in the Caribbean	The co-creation of a shared vocabulary in order to respond more effectively to natural disasters	Disaster response officials, university-based mobile technology developers, university academics	Diverse forms of governance, languages and institutional structures meant that collaboration around effective disaster-management response would be impossible unless a cohesive, shared vocabulary was designed and agreed upon by all actors
Online Virtual Herbarium in Brazil	Collaborative development of research and data governance framework	Biologists, programmers, students, researchers, herbariums	While the project emerged with the goal of making herbarium data "virtual" and "open" to the public in Brazil, a SWOT analysis and intensive negotiations with institutions, technicians, etc. showed that "openness" is not equally desirable or relevant for all actors.
Research Contracts with Indigenous Communities in South Africa	Co-design of a research contract that allows indigenous communities to define when, where and how their community knowledge is used by external researchers	Indigenous community leaders; law practitioners/researchers, feminist researchers	Indigenous communities in South Africa are diverse, with unique histories, languages and shared knowledge. Thus, there was a need for a flexible and inclusive research contract in order to secure the rights of communities during interaction with external researchers.

- 28 In what follows, we explain the contexts and details of the research projects summarized above, with a focus on detailing the various processes and changes that the projects undertook, and why, ultimately, a lens of intersectionality is important for planning, designing and assessing forms of inclusive knowledge infrastructures.

OCSDNet Case Studies: An Intersectional Approach to Knowledge Infrastructures

Case Study 1: Online Virtual Herbarium in Brazil

- 29 This project was led by a team within the Business School of the University of West Indies (MONA) in Jamaica. The team recognised that one of the core development challenges within the area was the ever-increasing scale of natural disasters, due to the effects of climate change and the persistence of poverty, which leaves poor citizens susceptible to injury and property damage due to habitation in low-quality structures. While most islands in the Caribbean are relatively small (in terms of population size and economic power), they experience the similar challenge of dealing with often-intense tropical storms. Given this shared challenge, the team recognised that there would be considerable advantage in collaboration between island states in order to respond more effectively to disaster situations. Thus, with the conception of OCSDNet in 2015, the team first proposed the development of a mobile phone application which they imagined would act as a virtual platform for collaboration between various disaster response units throughout the region.
- 30 However, as the team explored the potential for developing a mobile application for collaboration, they recognised that a key barrier was in fact a lack of consistent terminology between actors and institutions of different languages, economies, political structures and geographical distances throughout the region. Thus, tapping into a more “demand-side” approach to development thinking, the researchers adjusted their work plan in order to further investigate what tools and/or processes could be designed in order to develop a cohesive disaster-response vocabulary across diverse disaster-management actors in the region. The result was the eventual creation of what the team calls a “knowledge broker” for disaster management in the form of a collaborative, virtual thesaurus that could be used by diverse technical actors.
- 31 Nonetheless, even with an adjusted research agenda, the team soon recognised that in order to develop more effective and inclusive knowledge infrastructure, a considerable amount of time and effort would need to be spent establishing networks with the correct actors including high-level politicians, technical staff and disaster management units. Hence, the network-building component of this project was perhaps even more important than the digital tool that the team eventually created.
- 32 In order to facilitate collaboration between the research team and regional disaster management groups, the project leads consciously presented their work in such a way so as to align it with the objectives and outcomes of the regional management bodies. In that way, the leads ensured that the partners could see the benefits of collaboration and sharing of resources. By translating the project into language already used by the partner organizations, the leads were able to insert “openness” into an already-existing set of goals and enable government stakeholders to realize how the rather abstract concept of “openness” could actually be applicable to a number of their existing working areas.
- 33 In short, the team recognised that a technological tool could not simply be created to fulfill the needs of a wide array of stakeholders representing disaster management sectors across various Caribbean countries. Moreover, instead of simply supplying a new

and defined vocabulary for a diversity of actors, they directed their research actions towards network-building, alignment and consensus-making in order to collaboratively develop a disaster-management vocabulary that would be understood and easily accessible across countries and institutions of the region.

Case Study 2: Knowledge Broker for Disaster Management in the Caribbean

- 34 Given the rich biodiversity found in Brazil, large investments have been made into developing cyber infrastructures to support knowledge about Brazilian biodiversity (Barjak *et al.* 2013). In 2009, the Center for Reference in Environmental Information (CRIA), a non-profit Brazilian civil association established the Virtual Herbarium of Flora and Fungi (INCT) an e-infrastructure that provides the means for biological collections to share their data within a structured system responsible for data storage, search, retrieval, and visualization. The INCT documents, stores, disseminates, and increases the knowledge base on the diversity of plants and fungi of Brazil. Besides making 5-million data records and 900,000 images openly available, CRIA has developed new visualization tools to produce maps and graphs on-the-fly and compare images, thereby enabling cyber taxonomy. In 2018 (as of April 4, 2018), there are 472 datasets on the database.⁴
- 35 Prior to 2015, little attention had been given to analyzing the usage of INCT data as well as any incentives or barriers for openly sharing data through participation in the virtual herbarium network. But with OCSDNet support from 2015 to 2017, CRIA developed a project to critically assess network usage, evaluate whether the e-infrastructure was facilitating collaboration amongst scientists, and to understand whether open data was aiding users to create new forms of knowledge to help solve local development challenges.
- 36 One of the key methodologies used by the team to develop a SWOT (strength, weaknesses, opportunities, threat) analysis of the virtual herbarium as a form of open-knowledge infrastructure was a large-scale survey sent out to all users and data providers within the network. On the side of data users, the team found that over 90% of all users were Brazilian, which demonstrates the importance of having openly accessible virtual data available in order to support the creation of local knowledge. In addition, the majority of the users were students (of varying levels in their scholarly careers), but also included academics, local scientists, members of NGO's and the general public.
- 37 Interestingly, responses from the data providers within the virtual herbarium offered far more nuanced findings to contribute to the structuring of the network. In particular, the team found that the various institutions providing data to the network had often-conflicting conceptions of openness, which contributed to their willingness or restraint towards contributing data to the network. For instance, in an email survey, some institutions responded that they would not want to share species data that had not yet been published (due to fear of having the information stolen, and hence not being credited for their work); while others were afraid of revealing certain types of data—such as the locational information of high-value endangered species, due to the fear of having those specimens physically poached; potentially leading to species extinction. These examples highlight the complexity of developing knowledge infrastructures that are inclusive and open to a diversity of actors; openness is highly contextual and there are

many systemic dimensions and constraints which must be considered in taking account of how knowledge infrastructures should be designed.

- 38 As a result of their findings, CRIA developed a formal but flexible system for data providers to participate in the network. By providing technical options to open or “hide” different types of data, the data providers could choose which data they were willing to provide, rather than an all-or-nothing deal. For instance, a data provider could choose to set the name and image of a particular species as open, but the physical location of the same specimen hidden to the general public. In this way, the technical infrastructure still provides important reference data for general users, while also protecting the providers (and potentially the species) from data “poaching.”
- 39 In summary, while the Virtual Herbarium infrastructure was almost purely technical in its conceptualization prior to OCSDNet in 2015, the team came to realize that some of the most challenging aspects of creating a sustainable and accessible open access platform are the negotiations and models of collaboration between different institutions (with varying resources and priorities), as well as the disciplinary and vocabulary differences between botanists and ICT technicians. In the end, the team recognised that the creation of inclusive policies, a formal system of governance and sustainable long-term funding are all required to maintain the online database. In their final report, the team wrote: “For users to be able to rely on information systems, it is crucial for them to operate with uninterrupted, long-term funding... E-infrastructures require long-term maintenance and constant development, continuous and dynamic evaluation and planning, and efficient governance models to assure continuity of the network and its services,” (Canhos *et al.* 2017). Hence, similar to the findings of the Caribbean team from Case Study 1 above, this example reveals that while knowledge infrastructures may appear largely technical, the socio-political elements are most often key to making or breaking its usage and negotiating its inclusivity.

Case Study 3: Research Contracts with Indigenous Communities in South Africa

- 40 South Africa is home to a highly diverse group of people—including many indigenous groups that have lived throughout the southern tip of the continent for thousands of years. Historically, many of these communities lived in small, nomadic groups and have relied on intricate, generational knowledge of their environments in order to survive in the often-harsh climatic conditions that characterise much of Southern Africa. In 2014, a research team consisting of representatives from Natural Justice—a legal-research NGO in Cape Town—and academics from the United States applied to OCSDNet for funding. The team outlined a proposal that suggested developing research relationships with Indigenous South African communities in order to understand (and potentially “open up”) local knowledge that could be important for understanding the impact and implications of climate change throughout the region. The team suggested that by “opening” Indigenous knowledge to the general public, other South Africans and others could benefit from generations of indigenous expertise in dealing with harsh climatic conditions.
- 41 However, as the team began to approach communities, they were met with immediate distrust. On previous occasions, some communities had engaged with researchers and had often been the victims of knowledge exploitation, whereby some researchers would

extract local knowledge, for profit, without compensation for communities themselves. This is a phenomenon that has been increasingly documented (Tuck and Yang 2014; Smith 1999) in other localities. Therefore, the very idea of harnessing and “opening” community knowledge on climate change for the benefit of outsiders was met with great resistance.

- 42 In response, taking a similar approach to the Caribbean team outlined in Case Study 1, the research team in South Africa decided to adapt the project to what indigenous communities were demanding from a development perspective, rather than what the researchers felt would be most appropriate. Recognizing that communities were being exploited by external researchers, the OCSDNet team facilitated a process of developing a flexible and dynamic community-researcher contract, which would allow the community to negotiate, on (theoretically) more equal terms, with researchers and knowledge-profiteers with whom they might interact in future. As such, the idea of a community-researcher contract was determined to be relevant to implement for the project.
- 43 In this example, we view the community-researcher contract as an important example of an inclusive knowledge infrastructure. The research contract provides the framework, limitations and expectations for the sharing of knowledge from one party to another. Moreover, just as the Brazilian example has shown in Case Study 2, “openness” and the concept of “inclusivity” must be assessed critically: who is benefitting from open knowledge and who is exploited or excluded through these tools or structures?
- 44 The South African case study also reveals an example of the ways in which hierarchical knowledge structures might be challenged through the creation of new and inclusive knowledge infrastructures. For instance, in the design of the community-researcher contract, the team underwent intense negotiations with the American university partner, who sought to assert a universal application of research ethics and contracts for all research affiliates. As many academics are aware, these research-ethics contracts are often a one-size-fits-all model, structured solely by the university, and not by research participants themselves. The research team revised this top-down structure to create a more egalitarian contract that allowed the community to set the terms of exchange for their shared generational knowledge.
- 45 All in all, the research process and resultant infrastructure were deliberately strengthened through a series of back-and-forth discussions and negotiations over specific provisions of the community-researcher contracts. Through targeted efforts, the South African team refocused their research towards addressing community needs, rather than following the initial research agenda that would have contributed to the replication of existing power relations. Instead, by working with the community to develop a community-researcher contract, the team helped to lay out the rights and responsibilities of all parties, to ensure that local knowledge is used fairly and with permission. Hence, this form of knowledge infrastructure has important implications for future development research and opportunities.

Concluding Thoughts

- 46 A majority of work and practice in the field of Open Science has tended to overlook the importance of social structures and systemic constraints in the design of new forms of knowledge infrastructures. In this paper, we highlighted the importance of ongoing

negotiation and translation with a wide array of actors to develop infrastructures that are more inclusive to and mindful of the needs of diverse users and creators. In assessing the three OCSDNet case studies outlined above, we conclude that the concept of intersectionality provides a useful framework around which to understand the concept of “inclusive knowledge infrastructures.” Indeed, knowledge infrastructures must be mindful of the diversity of human needs, identities, abilities, experiences and forms of knowing. This finding also highlights the importance of cross-disciplinary learning. Open science practitioners can certainly benefit from the wide history of knowledge generated by decades of feminist scholars.

- 47 On the other hand, an intersectional framework also has its limitations. Within the cases outlined above, the meta-analysis of the projects was limited by the forms and types of data that the research teams themselves generated. Some OCSDNet teams had an explicit background and interest in social science and development and hence, were perhaps more attuned to the opportunity to assess the roles of gender, race and other complex identities within their projects. Other teams were from natural-science backgrounds, and often expressed difficulty in understanding the benefits of such an approach, and the potential relevance to their respective projects. In the latter instances, we were left with scant material for our own analysis. On the other hand, one-on-one interviews with project leaders permitted an indirect opportunity to gain insight around the dynamics of each team, including how the research process was planned and implemented and what tactics were used and learned in order to develop knowledge infrastructures that were inclusive (or not) of diverse actors.
- 48 It is important to re-emphasize that the three case studies highlighted in this paper are by no means attempting to offer a template model for creating more inclusive knowledge infrastructures, nor are they even necessarily offering particularly ideal or successful examples of inclusive infrastructures. Instead, we have sought to highlight how different histories, social and institutional systems, languages and cultural practices influence the way that different groups and individuals understand and desire “openness” in their respective circumstances. This, in turn, impacts the way that Open Science research processes are designed and ultimately the success or failure of more inclusive knowledge infrastructures. Intersectionality is offered as a way of critically assessing all of these themes and as a way towards realizing that both users and creators of infrastructures have complex, heterogeneous and (at times) conflicting needs and identities which should be accounted for in the design of new knowledge infrastructures.
- 49 Going forward, the OCSDNet coordination team seeks to understand how we might inspire and seed future research inquiries to more explicitly take notice of the ways that technology and research practices are intersectionally racialized and gendered, especially amongst research teams who may not have previous training or experience in feminist theory and practice. Indeed, this is an important question which we hope to see clarified in future iterations of the network.
- 50 Beyond OCSDNet, there is currently strong commitment from global institutions towards the development of physical infrastructure for sustainable human development. For example, the ninth UN Sustainable Development Goal (SDG) calls for the “building of resilient infrastructure, promotion of inclusive and sustainable industrialization and fostering of innovation” (UN 2017). Infrastructure has also become an increasingly common buzzword in various overlapping academic fields. However, in spite of all of the attention on infrastructure, little attention has been brought towards the idea of

developing more inclusive knowledge infrastructures, which we have defined in this paper as the tools, platforms, networks and other social and technical mechanisms that deliberately allow for multiple forms of participation amongst a diverse set of actors, and which purposefully acknowledge and seek to redress power relations within a given context. In an attempt to raise further attention to the importance of such infrastructures, this paper calls for the need to expand our thinking of what constitutes infrastructures, suggesting that a more direct focus on the creation of inclusive knowledge infrastructures is key for local development.

- 51 In this regard, Edwards *et al.* (2013) suggest that a more comprehensive focus on bringing “design thinking” into the creation of sustainable development infrastructures should be investigated, with a particular focus on encouraging user participation in the planning and design of tools and systems that are used on a regular basis. While this argument is important for the development of sustainable physical infrastructures as pursued by the SDGs, it is perhaps even more important (and needed) in the design of inclusive (and effective) knowledge infrastructures, such as those outlined within this paper. Nonetheless, uncritical adoption of design thinking methodologies should also be avoided as critiques have already identified the possible replication of many similar issues raised against participatory research methodologies, such as the replication of status-quo power relations when not facilitated responsibly (Cooke and Kothari 2001).
- 52 All in all, this paper and the case studies outlined seek to emphasise that there is no singular way of doing open science or producing new forms of knowledge. While discourse and practice in science tends to be dominated by a western-positivist worldview that posits tools and infrastructures as seemingly neutral and homogenous, this paper encourages a feminist approach to science and knowledge: one that recognises complex identities, histories, cultures and diverse forms of expression as invaluable for creating knowledge infrastructures that are deliberately and constructively inclusive.

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NOTES

1. ICT4D: Information and Communication for Development
2. MOOCs = Massive Open Online Courses, which are generally free and available for anyone to join online.
3. It is particularly important here to highlight the tension between setting up more decentralized infrastructures which are contextualized and aimed to meet user needs versus highly centralized system such as MOOCs which are controlled by already powerful actors. The latter appears increasingly to be subjected to control through the imposition of particular standards as forms of "soft governance" (Berg *et al.* 2016; Chen and Posada *forthcoming*).
4. See: <http://inct.splink.org.br/> for more information regarding the virtual herbarium repository.

ABSTRACTS

The current discourse around Open Science has tended to focus on the creation of new technological platforms and tools to facilitate sharing and reuse of a wide range of research outputs. There is an assumption that once these new tools are in place, researchers—and at times, members of the general public—will be able to participate in the creation of scientific knowledge in more accessible and efficient ways. While many of these new tools have indeed assisted in the ease of collaboration through online spaces and mechanisms, the narrowness of how infrastructure is imagined by open science practitioners tends to put the use of technology ahead of the issues that people are actually trying to solve and fails to acknowledge the systemic constraints that exist within and between some communities. Drawing on an analytical framework grounded in Black feminist intersectionality (Noble 2016), this paper highlights the need for more inclusive knowledge infrastructures, particularly in the context of sustainable development. Three case studies from the Open and Collaborative Science in Development Network (OCSNet), are outlined in order to illustrate the importance of moving beyond a definition of infrastructure as merely a technical or physical entity. These cases, arising from research conducted in South Africa, Brazil, and the Caribbean, demonstrate how more sustainable and nuanced forms of collaboration and participation may be enabled through broader understandings of knowledge infrastructures. This paper further argues that leveraging the feminist concept of intersectionality when conceptualizing the development of knowledge infrastructures could be one way to move from narrow assumptions about standardized knowledge “users” towards more inclusive reimaginations of how knowledges can be produced and shared via networked technologies.

INDEX

Keywords: inclusive knowledge infrastructures, open science, collaboration, research tools, participatory design, intersectionality

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