Transdisciplinarity, co-production and co-exploration: integrating knowledge across science, policy and practice in FRACTAL

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About FRACTAL working papers

This series is funded by the UK's Department For International Development (DFID) and the Natural Environment Research Council (NERC) through the Future Resilience for African CiTies and Lands (FRACTAL) project, within the Future Climate For Africa (FCFA) multi-consortia programme. The overarching objective of FCFA is to generate fundamentally new climate science focused on Africa, and to ensure that this science has an impact on human development across the continent. FRACTAL's main aim is to advance scientific knowledge on regional climate responses to global change and enhance knowledge on how to integrate this information into decision making at the city-region scale in Southern Africa. These products have been developed to share initial findings from research in the hope of fostering dialogue and eliciting feedback to strengthen the research. The opinions expressed are therefore the author(s) and are not necessarily shared by DFID, NERC or other programme partners.

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Acronyms and abbreviations

CSAG	Climate Systems Analysis Group
M-UF	Mistra Urban Futures
UCT	University of Cape Town
UKCIP	The UK's Climate Information Programme
UKCP09	UK Climate Projections 2009

Table of Contents

Introduction 2
Transdisciplinarity 3
Knowledge co-production 7
Co-exploration 11
Operationalising transdisciplinarity, co-production and co-exploration in FRACTAL 12
Team structure for transdisciplinarity, co-production: diverse yet intimate 13
Clusters of collaboration 13
City task teams 14
Processes for transdisciplinary knowledge co-production 14
City learning processes for facilitated, transdisciplinary engagement 14
Embedded researchers: consistent links between research, policy and practice 15
Learning and reflexivity to refine processes 15
Conclusion 15
References 17

Introduction

The Future Resilience of African Cities and Lands (FRACTAL) research project aims to contribute to creating more climate resilient and equitable development pathways for city-regions across the African continent, particularly relating to water, energy and food security. The FRACTAL project, which in its inception phase, aims to both advance scientific knowledge of southern African regional climate responses to human drivers of climate change, and enhance the integration of scientific climate knowledge into city-regional decision-making. The project aims to apply three forms of knowledge production, namely, transdisciplinarity, co-production and co-exploration.

FRACTAL is focussing on the context of nine southern African cities embedded in their regional context. It is widely documented that urbanization in Africa is taking place at an unprecedented rate, associated with complex demographic, economic, political, institutional, spatial, infrastructural and environmental transitions and transformations, which include high levels of informality (Parnell and Pieterse, 2014). Despite considerable investment and local ingenuity, an array of problems remains widespread in many African cities, including water, energy and food insecurity amongst many others. Within a globally and regionally changing climate, many of these problems are likely to worsen as cities grow (Pauleit et al., 2015). The persistence, and in many cases escalation, of these complex problems are evidence of the failures of dominant approaches to science, policy and practice. New ways of bringing science, policy and practice to bear on these evolving problems are therefore needed.

The project therefore acknowledges the growing critique of the science-society binary which conceptualises science as expert knowledge to be 'inserted' into society in a top-down manner (Whatmore, 2009, 2011). The orthodox literature calls for 'evidence-based policy making' with science having the most authority over other knowledges in providing this evidence and hence directs policy-making (Lane, et al., 2011). This is a linear, knowledge-driven model where knowledge production is viewed as rational, valuable and apolitical, and feeds into the policy process (Jones, 2009). There has been much critique of this thinking and governments are starting to recognise that there are different types and forms of knowledge that may all be useful to, if not necessary for, effective policy-making. These include expert, practitioner, lay and indigenous knowledge, natural and social science knowledge, and qualitative and quantitative knowledge.

There is a growing discourse that promotes the notion that research has a use value to stakeholders or the general public and with this has emerged a growing focus on researchers engaging with the relevant stakeholders in order to create 'pathways to impact' (Bracken et al, 2015, 2). Research is thus increasingly being designed to integrate the research results into decision-making and practice in various contexts and that this involves the exchange of knowledge (Bracken et al, 2015, 2). The assumption here is that 'expertise is widely distributed' and that scientific and local knowledge need to be included in finding solutions to the environmental and social problems at hand, thus

broadening what constitutes 'admissible knowledge' (Whatmore, 2009; Lane et al., 2011). The FRACTAL research project is such a project which aims for scientists, policy makers and civil society actors to engage with policy and practice at the local level in order that the science is socially relevant and appropriate.

To achieve this aim in FRACTAL, the concepts and practices of transdisciplinarity, knowledge co-production and co-exploration between researchers, decision-makers operating at the city, regional and national scales, and other civil society and private sector knowledge-holders are being increasingly built into the ongoing design and implementation of the project. The aim of this working paper is to present these three concepts and approaches of transdisciplinarity, knowledge co-production, and co-exploration and their challenges, and how they are being operationalised in FRACTAL. The question asked is whether these concepts and their processes have shown to cross or blur boundaries between science and society and policy and practice.

It is recognized here that the early articulation of the project's aim was perhaps problematic in that it could be interpreted as projecting a dominance of science over policy, or scientific knowledge over policy knowledge, which would run counter to the three concepts and approaches being discussed here. It is exactly this prevailing tension that provides the motivation for producing this working paper. During the process of developing the FRACTAL proposal and building the project team, the complexity of the problems being addressed and the diversity of potentially relevant and necessary knowledge for addressing these problems have become increasingly appreciated.

What is the thinking about the production, circulation and use of knowledge that underpins FRACTAL's ambitions, and how might this work in practice? Now that the FRACTAL project is moving ahead and collaborations are being established amongst a broad and diverse set of partners and stakeholders, it is important that we build a shared understanding of what concepts and practices are being used in the project. In this FRACTAL Working Paper, we briefly reflect on the history and conceptual trajectory of transdisciplinarity, knowledge co-production and co-exploration, and then suggest how they are being used and operationalized within the FRACTAL project. The intention is to capture our current thinking in the first year of the project and then revisit these understandings near the end of the project to reflect on how our thinking and practices may have evolved and changed through implementing the project. This ambition of learning and reflexivity is a core principle of the transdisciplinary approach to research, as discussed in the next section.

Transdisciplinarity

The concept of transdisciplinarity, used as early as the 1970s, is proposed as an approach to knowledge that "transcends the narrow scope of disciplinary worldviews" (Klein, 2013, 69). Since the last decade, thinking and working in transdisciplinary ways has become

increasingly popular and widespread. New research centres and programmes are being set up around the world to undertake transdisciplinary research and policy-making, for example Future Earth and Mistra Urban Futures[1]. FRACTAL is part of this trend.

Transdisciplinarity represents a major epistemological shift, marking a change in the way knowledge is conceptualised, created and assessed. There is no single universal theory, method or definition of transdisciplinarity. Rather ideas and methods are being drawn from across a wide range of fields and perspectives to create a plurality of definitions (Klein, 2013). Common across these is the view that, in order to better understand the complexities and uncertainties of contemporary society, and to address the problems or challenges emerging within this complexity, various types of knowledge and ways of creating knowledge from across academic disciplines and from sources outside of academia need to be brought together. The problems of society, as conceptualized and expressed by various actors or knowledge-holders operating outside of academia, are valued equally to research problems articulated by academics and are used to jointly co-frame and co-design the pursuit of new, additional knowledge to address complex challenges (Austin et al, 2008; Klein, 2013).

A common theme among numerous definitions of transdisciplinarity is that it is a type or mode of knowledge production different from disciplinary, multidisciplinary and interdisciplinary modes of producing knowledge. Disciplinary knowledge production takes place within the confines of the conceptual and methodological boundaries of a discipline, while multidisciplinary research involves a range of disciplines working in parallel but in a co-operative fashion around a common research question, each contributing their disciplinary expertise (Austin et al, 2008). The shift from multidisciplinary to interdisciplinary research involves the integration of concepts and methodologies from a range of disciplines to jointly determine the problem to focus on, the research questions to address, the conceptual framework to guide the research and the methods to be applied (Klein, 2013; Darbellay, 2015). Transdisciplinarity, in turn, entails the further integration of other forms of knowledge from beyond the disciplines of academia in order to address the complexity of contemporary problems in society. It thus unsettles the conventional binary understanding of the relationship between science and society, which views the two as separate realms. The binary view positions science as producing independent expert knowledge and society as acting on that knowledge, i.e. a 'deficit model' of science feeding knowledge into practice, with concepts such as the 'producers' and 'users' of knowledge being used. By contrast, transdisciplinary research involves multiple knowledge-holders collaborating as equals to construct more contextualised and socially embedded understandings of, and solutions for, real-world problems (Polk, 2015) often transforming disciplinary identities (Darbellay, 2015).

*The important thing about **transdisciplinary** research is that the process of producing new knowledge integrates the perspectives, practices and knowledge of*

[1] See http://www.futureearth.org/ and http://www.mistraurbanfutures.org/en

academics, practitioners and local people (across the public sector, civil society, business, industry and commerce) in order to make the resulting knowledge more relevant and applicable to taking action on the shared problem of interest or concern.

One of the main characteristics of transdisciplinary knowledge production is that there are alternative criteria and measures to those of conventional positivist science for assessing the quality of the knowledge and the knowledge production process[2]. The main criterion for assessing the validity of knowledge within the positivist paradigm is that of objectivity. By contrast, the criteria for assessing transdisciplinary knowledge include the social acceptability and legitimacy of the solutions to problems, as well as the methods used (Wickson et al, 2006; Ravenek and Rudman, 2013; Culwick and Patel, 2016). By bringing together and integrating various disciplines, transdisciplinarity requires bridging between different paradigms or ways of knowing[3].

Transdisciplinarity recognises, values and integrates marginalized ways of knowing together with the scientific modes of thought that are often privileged and dominant (Klein, 2014). (See Box 1). It has been suggested that the popularity of transdisciplinary approaches is being driven by demands for more participatory, democratic and inclusive modes of knowledge production and decision-making, called for by an increasingly engaged public (Funtowicz and Ravetz, 1993; Wickson et al, 2006; Lotz-Sisitka et al, 2016). This is accompanied by calls from within environmental fields for transdisciplinary knowledge to better understand the complex relations between society and the environment in order to address what need to be thought of as socio-natural problems of sustainability (Wickson et al, 2006; Vogel et al, 2016).

The literature highlights many challenges associated with capturing multiple framings of a problem, integrating diverse knowledge and contributing to societal change that transdisciplinary research demands (Swilling, 2014; Polk, 2015; Vogel et al, 2016). These challenges include: the difficulties experienced by academics in giving up control over the research process and the ownership of knowledge; the large amount of time, energy and

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[2] Positivism is the view, or philosophical position, that there exists an objective real world independent of our senses and perception of it, and that authentic knowledge of that real world is logical and objective, unaffected by values and morals. Such 'authentic knowledge' can only be attained through systematic observation and measurement and the logical development and testing of statements, rules or laws to explain and predict observed phenomena (i.e. the strict application of the scientific method) (Lincoln et al, 2011; Sharp et al, 2011).

[3] With the increasing critique of positivism as an approach to understand the social world, a wide range of post-positivist philosophies and social theories have emerged in the last four decades and this can broadly be called the "the interpretive turn in the social sciences" (Mottier, 2005; Pryke et al, 2005). Post-positivist, interpretive approaches aim to construct the meaning of the people's understandings and experiences and how they make sense of their everyday activities, Subjectivity is a central component of this approach and social reality is not seen as exterior but as a lived construct. The research process is considered to be reflexive with constructions of meaning co-constructed by the researcher and the research subject. Data are therefore not external social facts but are socially constructed (Mottier, 2005).

funding transdisciplinary projects require; the building up of trust and collaborative partnerships on an equal basis; developing a shared language to transcend disciplinary concepts and conventions; the uncertainty of the process which has to be individually and iteratively designed for every context; and the uncertainty of the outcomes. These challenges cannot be eradicated but it is intended that they be problematised in the research design. As such, Harris and Lyon (2014) usefully suggest five core elements of a transdisciplinary approach, which are:

1. Living with tensions: Transdisciplinary research requires managing diversity and "tangled agendas" to navigate tensions. There is no one correct methodology.
2. Formation of a diverse team: Teams need to be big enough to be diverse but small enough to build relationships.
3. Negotiating the research approach: Develop methods of engaging all partners. Workshops, meetings, calls, seminars, webinars and communiques can be key to ensuring good communication, managing expectations and ensuring equality among all participants.
4. Knowledge creation: To avoid the pitfalls of a multidisciplinary or multi-stranded approach, transdisciplinary projects need to ensure integration of all aspects of the research. Allow time and space to disagree, debate, test alternatives and learn from mistakes. Time for co-reflection and learning needs to be written into the project and protected. In addition to creating the time and space, the processes of navigating and productively using these ruptures and moments of insight need to be skilfully facilitated.
5. Outputs: Negotiation is required at an early stage to ensure outputs satisfy all team members, as well as funders. The quality of the process needs also to be considered an output.

Some of the challenges of undertaking a transdisciplinary research project and ways of addressing them are discussed in relation to the iShack project in box 1, where a diverse project worked collaboratively to improve living conditions in Enkanini (an informal settlement near Cape Town, South Africa) to surface potential lessons learned from this project for FRACTAL.

Box 1: Learning from the iShack project

The iShack project was initiated by the Centre for Complex Systems in Transition and the Sustainability Institute at Stellenbosch University in 2010 and is ongoing. This project aims to find near-term solutions to electricity, water and sanitation problems facing residents living in the Enkanini informal settlement (near Stellenbosch in South Africa) through a transdisciplinary process. The diverse project team, including Stellenbosch University academics and students and members of the Enkanini community, has constantly renegotiated their research approach since the beginning of the project. Although the initiative had broad objectives to focus on issues related electricity, water and sanitation, workable solutions for the socio-economic context of Enkanini needed to emerge through engaged research. Given the uncertainty around specific outcomes of this research, knowledge from community actors was blended with scientific knowledge in an iterative and emergent manner to find workable solutions to the issues discussed above. Such an approach has been somewhat contentious for this project because it is managed primarily through a university, which traditionally creates and owns knowledge. Yet it is acknowledged that this bottom-up approach, framed within a deep understanding of the context of the settlement, is necessary for projects, such as FRACTAL, that aim to deal with complex and location-specific problems.

For further details see: Boix-Mansilla, V., Chua, F. and van Breda J. 2010. Case study: Incremental upgrading of Enkanini – the iShack Initiative. Available at: http://www.interdisciplines.eu/paper.php?paperID=292

Knowledge co-production

Fuelled by the promotion and proliferation of transdisciplinary approaches, the idea of co-producing knowledge has also been on the rise since the early 2000s. Attempts at co-producing knowledge are particularly evident in the sustainability field, aimed at dealing with issues of complexity and uncertainty by acknowledging the limits of scientific knowledge to fully explain or predict outcomes and select optimal actions for building a sustainable future (Polk, 2015; Pohl et al., 2010).

Like transdisciplinarity, ideas and practices of co-producing knowledge challenge the positioning of science as a superior source of knowledge, and critique the top-down binary models of transferring knowledge from academia to 'end users'. This underpins a shift from aiming to produce knowledge that is scientifically robust to (co)producing knowledge that is also socially robust and thereby more readily applicable for addressing real-world problems in a given context (in contrast to only solving 'blue sky' theoretical problems). Co-production thinking argues that in order to achieve this requirement of both scientific and social robustness, the boundaries between science, politics and practice need to be better understood and then, if needed, be crossed or transgressed based on deep engagement and collaboration between all relevant actors, i.e. those traditionally operating inside, outside and between science, politics and practice (Nowotny *et al*., 2001; Lemos and Morehouse, 2005). Concepts of co-producing knowledge build on and extend earlier thinking and practice of participatory action research (Elden and Levin, 1991) and interactive research (Scott et al., 1999; Wolgar, 2000; Robinson and Tansey, 2006).

*In essence, knowledge **co-production** involves the combining of two or more different types of knowledge, skills and working practices by bringing together people who think and act in often very different ways in order to create new knowledge for addressing societal problems of shared concern and interest.*

Processes of co-producing knowledge require that no one actor or discipline claims superior knowledge of the question, issue or problem being addressed (Pohl et al., 2010; Oldfield and Patel, 2016). A dialogue based on mutual respect is required between people and groups of people with different knowledge and ways of thinking. This redistribution of power over shaping the research agenda, knowledge production process and outcomes has proved challenging. This is especially true for academics, who are used to driving research projects, and for those actors, whether in the public, private or civil society sectors, who are used to commissioning tightly defined, prescriptive pieces of research from consultants.

In addition to challenges associated with breaking down power imbalances, three other important challenges are associated with co-producing knowledge (Pohl et al., 2010). The first is integrating different types and scales of knowledge and worldviews across multiple boundaries – between science, policy and practice, between disciplines, across organizational levels, between the public and private sectors, and between formalized, codified and informal, tacit forms of local knowledge (Cash et al., 2006). The second challenge is dealing with multiple and contested normative agendas, in the sense that each actor holds a view on what they consider to be the desirable outcome or goal of producing knowledge and the 'correct' or most appropriate way of doing so, and this will differ between individuals and groups participating in the knowledge co-production process. The third challenge, with strong linkages to the others, is negotiating the products or deliverables of the knowledge co-production process. Usually the participants have their own requirements for what these might be, for example a scientific journal paper, a policy brief, a practical handbook or a decision-support tool, and so an important step in the process is agreeing to how the jointly produced knowledge can and will be used, by whom, using what resources and to what end.

Addressing these challenges requires that, in addition to people contributing their knowledge and expertise (whether practical, policy based or scientific), some organizations and individuals involved in the process of co-producing knowledge take on the roles of:

1. *convenor*, bringing parties together for face-to-face engagements;
2. *facilitator*, fostering trust, openness, deliberation and shared learning;
3. *translator and intermediary*, making different ways of knowing visible, explicit and understandable to others (both literally between languages and conceptually between worldviews based on different sets of assumptions) and linking them around common themes; and

4. *mediator*, representing and evaluating different interests and resolving conflicts over goals (in addition to disagreements over facts) so that mutual gains can be made and value created in a way that leads to perceptions of fairness and procedural justice by all those involved (Cash et al., 2006; Pohl et al., 2010).

In some cases, these roles might be taken on by researchers, but this requires a special kind of researcher who is willing and able to step away from being primarily a contributor of content to focus on the quality of the engagement and collaboration process to facilitate change in the cities. Equally, these roles can be taken on by others in the co-production process. This requires that the first challenge has been overcome such that the researchers are not insistent on remaining in the driving seat in terms of directing and controlling the production of knowledge.

Co-producing knowledge is about finding ways to foster collaboration between scientists, decision-makers and practitioners (in the public, private and civil society sectors). This collaboration needs to enable the decision-makers involved to better solve problems they are tasked with addressing and be more influential in shaping the outcomes of contested decision-making processes (based on social legitimacy and scientific credibility). Researchers need to be able to satisfy their curiosity, be published and progress their scientific field through the collaboration. The practitioners involved need the collaborative engagement to enhance their practice and implementation of actions such that they can more effectively achieve their intended outcomes and show impact.

Ideas about co-producing climate-related knowledge began surfacing in the mid-2000s. Lemos and Morehouse (2005), Cash et al. (2006) and others suggested that to better understand and address climate risks requires increased engagement and collaboration between scientists and decision-makers. The UK's Climate Information Programme (UKCIP) was one of the early efforts within the climate science community to put some of these ideas into practice by facilitating collaborations between university-based climate researchers, policy-makers in the UK national government and practitioners in many local government authorities tasked with factoring current and future climate risks into their decision-making (Hedger et al., 2006; Gawith et al., 2009). Box 2 provides one UKCIP example of attempting to co-produce climate knowledge and what this potentially suggests for the FRACTAL project.

Box 2: Learning from the UK Climate Projections 2009 Users' Panel

UK Climate Projections 2009 (UKCP09) is a climate analysis tool, funded by the UK government, featuring a suite of guidance material, graphical displays of potential future climate change and datasets. It was designed to help UK decision-makers assess their risk exposure to the climate and make informed choices about adaptation. During the development of the UKCP09, a Users' Panel was established to guide the development of the projections. The panel, coordinated by the UKCIP, consisted of 40 users and scientists, all engaged in the development and presentation of the new climate projections. Panellists included climate science researchers, technical sectoral experts, policy makers and local authority representatives. The remit of the Users' Panel was to work closely with the development team to ensure the projections met the needs of target user communities, as well as to guide the usability of the UKCP09 documentation, including its supportive user interface and training. Over the 3-year development period, the panel met face-to-face on a quarterly basis and had email and webinar interactions between meetings. Despite the best intentions, the co-production environment was still driven by climate science endeavours, with limited opportunity for the users to shape the methodology to projections develop projections (Steynor et al., 2012; Street et al., 2009). The influence of the panel was limited to shaping the presentation and delivery of the projections and their associated guidance. This illustrates how challenging it is to co-produce knowledge. A key lesson from this experience for the FRACTAL project is to acknowledge the significant resource capacity and commitment required to fully engage in a co-productive approach that bears efficacious and sustainable results.

The FRACTAL project team includes people who were involved in UKCIP, so many of the practices and lessons learned continue to inform the work of FRACTAL. Similarly, phase 1 of the Swedish-funded Mistra Urban Futures (M-UF) programme had the aim of co-producing knowledge on urban sustainability, involving universities, city governments and the public in Gothenburg (Sweden), Greater Manchester (UK), Kisumu (Kenya) and Cape Town (South Africa) (Polk, 2015; Patel et al., 2015; Greyling et al., 2016). The Cape Town component of the M-UF programme included the embedding of researchers from the local university in the city government over a three-year period (Mistra Urban Futures 2016, see chapter 6). Knowledge and experiences from phase 1 of the M-UF programme have been influential in shaping the design and activities of FRACTAL, notably the use of embedded research as one modality for facilitating the co-production of knowledge.

As can be seen from reviewing literature and experiences of transdisciplinarity and co-production, there is a great deal of overlap between them. The emergence of these two processes of knowledge production started in different fields seem to be converging. For example, Polk (2015) has recently published a paper on 'Transdisciplinary co-production' and Klein (2013), using the idea of 'keywords', shows the overlap of the thinking behind transdisciplinarity and co-production in her paper titled 'The Transdisciplinary Moment(um)'. In this paper we accept that transdisciplinarity and knowledge co-production are in effect the same thing, despite the two terms being used separately in different research foci of the FRACTAL project. The important common element in these two processes of knowledge production is that the boundaries between science and policy, and policy and practice are crossed.

Co-exploration

Partly in reaction and resistance to the output orientation of knowledge co-production, which has new knowledge as the focal point, the idea of co-exploring knowledge and decisions has emerged in recent years within the climate change field. Co-exploration, as a concept and an approach, is being developed and propagated by a range of actors working in the climate services space, including the Climate Systems Analysis Group (CSAG) at the University of Cape Town (UCT), which leads the FRACTAL project (Steynor el al, 2016).

> ***Co-exploration*** *is a process by which scientists, policy-makers and practitioners work together to identify and articulate where there is a demand for climate information and provide a new kind of scientific service in support of climate-resilient decision-making.*

The idea and practice of co-exploration is still in a formative stage, being actively developed and tested in numerous projects, including FRACTAL. Co-exploration is currently used to mean a participatory process that brings climate scientists, policy-makers and practitioners together to ask questions of each other, share knowledge, and develop a joint understanding of what is potentially needed of climate science by decision-makers and what is scientifically feasible and defensible in terms of meeting that need. This means that the boundary between science and policy is not crossed. Box 3 provides an example of co-exploration being practiced in a workshop setting.

Box 3: Learning from co-exploratory climate risk workshops

The co-exploration concept was tested in two regional workshops held in Dar es Salaam and Accra in 2013 and 2014 respectively (Steynor et al, 2016). The workshops were designed to co-explore urban risks and vulnerabilities sensitive to changes in the climate. The participants included experts in the fields of meteorology, climatology, agriculture, water resource management, disaster risk management and land-use planning, drawn from government, university and non-government spheres. During these workshops, the interactions among multi-stakeholder groups were structured through a series of steps. The steps involved 1) identifying units of exposure (e.g. water supply and crop production) and place-based stressors (e.g. urban encroachment, improper waste disposal). 2) The stressors were then ranked according to their influence on the exposure unit. 3) Response strategies were developed to address high ranking stressors and 4) climate information was integrated in the final stage to assess the long-term effectiveness of each strategy. The co-exploration process provided an opportunity for knowledge to be shared across disciplines. Users of climate information were exposed to evaluating multiple sources of climate information. The climate scientists gained insights into the complexity of the decision-making process and how climate factors interplay with competing demands and interests. One of the main challenges faced in the multi-stakeholder groups was an unfamiliarity with or misunderstanding of each other's terminology. Another challenge was how to sustain the engagements and process of co-exploration beyond the workshop to leverage the learning and trust-building that took place. This is one example of a step-based approach to co-exploration in workshop setting, but co-exploration could take on many other forms. The intention is to develop and test some of these alternatives in the FRACTAL project.

In some instances, co-exploration may be a pre-curser to knowledge co-production in that it builds the basis needed for co-production activities, e.g. forming relationships, building trust and understanding each other's needs and framing of the issues, thus blurring the boundaries between science and society. However, the process of co-exploration does not have the primary intention of using the engagement to inform research and the (co)production of new knowledge. Rather the focus and main aim of co-exploration is to build the relationships and understanding needed to package, provide and communicate existing scientific data, information and knowledge in a way that is more relevant, accessible and useful to decision-makers.

Co-exploration does not begin with the assumption that climate data, information or knowledge is necessarily needed. Rather it begins by exploring the development and resource management context in which the decision-makers are operating and then whether climate data, information or knowledge is needed, and if so what information is specifically relevant to the decision(s) and how can it be most effectively provided. A range of related issues, including the ethics of how such information is created and used, arises through such co-exploration engagements, which is an emerging area of research (Hewitson and Vogel, 2016). The FRACTAL project is intended to be an important arena in which to test and further develop the concept of co-exploration with the partners and stakeholders involved. This approach to knowledge still maintains the binary of science and society, although the co-exploration allows for more demand-driven, or at least demand-informed, science. This applied work in climate science is emerging as a new field called 'climate services', in which research institutions and consultants provide climate data, information and expert analysis for 'clients' (e.g. agricultural extension officers and farmers) to use in their decision-making. So here there seems to be no actual crossing of boundaries, but possibly rather a case of talking through the fence.

Operationalising transdisciplinarity, co-production and co-exploration in FRACTAL

As stated above, the knowledge production processes of transdisciplinarity and co-production are very closely aligned, and therefore will be used as one approach, i.e. transdisciplinary co-production, while being further interrogated, explored and experimented with in the FRACTAL project. By its very nature, this knowledge production process requires crossing, and maybe in some cases blurring, the boundaries between science and society. By contrast, co-exploration refers to interactions at the interface between science, policy and practice that share and interrogate existing knowledge and knowledge needs. Hence it maintains science and society as binary categories. In the FRACTAL project we are operationalizing the concepts and associated practices of both co-exploration and transdisciplinary co-production in different ways to engage various partners and actors in the project activities and meet the aforementioned aims of the project. Importantly, it is not expected that all knowledge will be co-produced in a transdisciplinary way in the project. Rather, space is provided in the project for traditional disciplinary research and scientific knowledge production to co-exist alongside, yet

regularly interact with, transdisciplinary efforts at co-producing new knowledge that is both scientifically and socially robust.

So how, in practical terms, is FRACTAL operationalising the concepts reviewed above in an attempt to produce knowledge that meets societal goals? How is the team minimising the challenges associated with these somewhat progressive research methods that have been highlighted by many experts in the field (Swilling, 2014; Polk, 2015; Vogel et al, 2016, Cash et al., 2006; Pohl et al., 2010)? During the inception phase of the project, feedback and reflections from FRACTAL team members based on their initial experiences have already, in many instances, aligned with the challenges that appear in the literature. To facilitate co-exploration and transdisciplinary knowledge co-production in the project, much time and effort has been invested in developing appropriate organisational structures and processes, which are described in detail below.

Team structure for transdisciplinarity, co-production: diverse yet intimate

The composition of projects such as FRACTAL, through which transdisciplinary knowledge co-production and co-exploration research activities are implemented, is characterized by a number of organizational attributes that contribute to the effectiveness of the project. It is important to note that these structures are evolutionary, and potential exists for new structures to emerge or present structures to change as lessons are learned.

An important aspect of FRACTAL that facilitates transdisciplinary work is the diversity of organizations and individuals involved as project partners, and in the broader community of practice. This includes a range of universities, research organizations, networking organizations, consultancies, city governments, civic organizations, funding agencies and private enterprises (27 institutional partners in total). The core FRACTAL team is large, comprising more than 60 individuals from these various organisations. These team members represent a wide array of disciplines and backgrounds including those related to *inter alia* climate science, ecosystem restoration, government, governance, hydrology, philosophy of science, physical modelling, spatial planning and town planning. Within this broader FRACTAL team, smaller operational units have evolved to undertake tasks, and manage research and engagements. These smaller units provide for more intimate working environments, within which relationships are steadily being built.

Clusters of collaboration

Clusters of collaboration have been set up to cut across various boundaries, between disciplines, organizations, sectors, and work packages[4] to focus on particular research themes. This has been a deliberate attempt to move beyond multi-disciplinary ways of

[4] The FRACTAL proposal was structured into three Work Packages (WP) that map onto the three pillars of the Future Climate for Africa programme. WP1 develops city pilot studies. WP2 deals with understanding decision-making at the city-regional scale and entry points for incorporating climate information. WP3 advances knowledge of the physical climate processes driving the regional system.

working in parallel, to working collaboratively to frame questions, design methodologies, plan activities and undertake tasks in a transdisciplinary way. The four research clusters that drive the continued design and implementation of FRACTAL research are: city learning, climate information, decision-making and nexus. A cross-cutting cluster also exists to coordinate tasks across the four research clusters. It must be mentioned that although these clusters are dynamic and project team members are encouraged to be part of more than one cluster, the research within each cluster is driven by experts in the field, and space for disciplinary research (particularly related to climate science and governance) is also protected within these clusters. Outputs from this disciplinary research in turn feed into processes of transdisciplinary knowledge co-production.

City task teams

Task teams have been set up on a voluntary basis to facilitate engagements between the FRACTAL team and the city partners (the local university and city council). These task teams have been mandated to organise logistics, and to design city learning processes. Teams include representatives from academic institutions, the local municipality, and the university in each city, which supports a transdisciplinary approach in the design and implementation of city engagements. Importantly, this structure enables different knowledge types and perspectives to be integrated into these processes, which are described below.

Processes for transdisciplinary knowledge co-production

The main objective of FRACTAL is to co-produce climate knowledge that meets societal goals in each of the cities in which the project is working. The focus of this output is defined by all stakeholders (including civil society actors from the cities in which FRACTAL is working) through careful negotiation at the initial learning labs, and refined through a number of processes as the project progresses. These processes support the co-production of relevant climate knowledge that satisfies the needs of the whole project team, particularly the city partners.

City learning processes for facilitated, transdisciplinary engagement

Learning labs and city dialogues are spaces of learning in FRACTAL that periodically convene, within the cities, a broad range of knowledge-holders and interested parties. Here, through processes that are facilitated by members of the FRACTAL team, a deeper understanding of shared 'burning issues' of the city related to the over-arching project agenda (i.e. climate, water, energy, governance) is gained through discussion, negotiation and knowledge-co-production. The *learning labs* are relatively large, biannual (at least) events that take place in the cities, and are designed to be emergent and co-productive in the sense of gathering people from diverse disciplines and backgrounds in a room to generate a joint knowledge output. Between these learning labs, a series of smaller, more focussed *city dialogues* are convened to deepen understanding of a part of the city's burning issue as the basis for research activities. These smaller city dialogues can be co-

exploratory or co-productive in nature, depending on the timing, focus and need. The *city dialogues* centre on outputs that both inform and are informed by the learning lab events.

Embedded researchers: consistent links between research, policy and practice

Central to the design and operations of FRACTAL is the deployment of *embedded researchers* in each city to operate as intermediaries between researchers, city officials and politicians. Each embedded researcher has a mandate to ensure ongoing and effective communication, data and information flows between researchers, policy-makers, officials and practitioners. This intermediary role is seen as critical for driving the transdisciplinary research agenda in each city, and enabling both co-exploration and co-production of knowledge.

Learning and reflexivity to refine processes

In an attempt to improve the processes that enable knowledge co-production, special attention is paid to learning in FRACTAL. The project aims to foster an authentic and iterative learning process that moves beyond simple measurements of milestones and targets to deeper reflexivity and adjustment. It is recognised that lessons are learned at three interlinked scales – the city scale, the project scale, and the broader Community of Practice scale – each of which can be used to inform and improve project activities. Lessons learned at each of these scales are shared through various communications, for example webinar sessions after every city dialogue or learning lab event. This learning process enables reflexivity, with an emphasis on regular reflection and looping lessons learned back into project activities to address challenges and thereby ernhance our research and practice.

Conclusion

It is already clear within FRACTAL that doing justice to ideas of co-exploration and transdisciplinary knowledge co-production is not easy, far from it. Realizing the ambitions of the project requires working through numerous challenges, many of which mirror those raised in the existing scholarly literature on transdisciplinarity, knowledge co-production and co-exploration reviewed for this Working Paper. Consequently, as the FRACTAL project team, we need to continue making every effort to build off past experiences (like those profiled in the boxes above), while regularly reflecting on, learning from and adjusting the FRACTAL processes as we proceed with implementing the project. Recognizing the challenges associated with communicating and engaging with the complexities and ambitions of the FRACTAL project, the infographic below was developed as one way of conveying the core elements of the project, many of which are described above and in other FRACTAL Working Papers in this series, available here: http://www.fractal.org.za/working-papers/


FRACTAL
FUTURE RESILIENCE FOR AFRICAN CITIES AND LANDS (FRACTAL)
Growing Climate Knowledge for Action in Urban Africa
climate
better understand southern Africa's climate, its drivers and systemic impacts on city-regions
multiple scales
Explore connections between climate sensitivities and decision-making at urban, national and regional scales
governance
better understand decision-making in southern African city-regions on water, energy, food and climate issues
Blantyre
Cape Town
Durban
Gaborone
Harare
Johannesburg
Lusaka
Maputo
Windhoek
learning labs
multi-stakeholder learning processes to co-explore and co-produce knowledge on climate-sensitive 'burning issues'
city dialogues
various city-based trans-disciplinary engagements beyond and between the Learning Labs
city regions
fostering context-relevant yet transferable learning within and between 9 city-regions, to varying degrees
City learning
ongoing and iterative learning processes (including learning labs and dialogues) that drive the co-production of relevant climate knowledge

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