Inclusive, participatory and reflexive learning processes for climate resilience: key lessons from FRACTAL

Alice McClure

FRACTAL Working Paper *#9* | *March 2020* |

FUTURE CLIMATE FOR AFRICA

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FRACTAL

Future Resilience for African Cities and Lands (FRACTAL) is a trans-disciplinary group of researchers from partner organisations around the world. Together with a broad range of stakeholders, they are working to co-produce relevant knowledge that will support resilient development pathways and enable decision-makers to better integrate pertinent climate knowledge into their resource management decisions and urban development planning. FRACTAL is a four year project within the multi-consortia Future Climate for Africa (FCFA) programme - jointly funded by the UK's Department for International Development (DFID) and the Natural Environment Research Council (NERC).

These knowledge products have been developed to share findings from the research in the hope of fostering dialogue and eliciting feedback that strengthens the research. The opinions expressed are those of the author(s) and are not necessarily shared by DFID, NERC or other programme partners.

About the author

Alice McClure | FRACTAL coordinator

Climate Systems Analysis Group, University of Cape Town, Cape Town, South Africa

alice@csag.uct.ac.za

With special thanks to Anna Taylor and Tamara Janes for reviewing the working paper

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1. INTRODUCTION

This working paper describes several approaches that have been adopted within the Future Resilience of African CiTies And Lands (FRACTAL) project to document, explore and pull together key messages about inclusive, participatory and reflexive learning processes[1], particularly how these contribute to solving climate-related problems in southern African cities. FRACTAL is part of the Future Climate For Africa (FCFA) multi-consortia programme (funded by DFID and NERC), which has the overarching objective 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 objective is to *advance scientific knowledge about regional climate responses to anthropogenic forcings, and to enhance the integration of this knowledge into medium to long-term decision making at the co-dependent city-region scale that responsibly contributes to resilient development pathways*. Disciplinary, interdisciplinary and cross-disciplinary learning processes are core to achieving this objective. Researchers from institutions across the globe have undertaken work to advance understanding of the climate system and processes (including how this might change in the future), governance and resource management in southern African cities, as well as connections with the broader geographical region. Through this work, research frontiers related to the climate system and cities in southern Africa have been pushed in FRACTAL.

Climate change falls within the category of problems for which "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz, 1993). The FRACTAL team aimed to move beyond the framing of climate change problems and solutions within the academic paradigm and to involve an "extended peer community" to produce knowledge that is relevant and actionable in southern African cities (Klein, 2013; Funtowicz and Ravetz, 1993). Inclusive, participatory, contextual, reflexive learning processes were at the core of much FRACTAL work to better understand these issues (see Hewitson et al. 2014). It must be noted that individuals and groups in FRACTAL experienced learning in many ways; this study did not aim to capture all these learnings. The objective was rather to consolidate and document the inclusive, participatory, contextual, reflexive methods that were implemented based on empirical evidence, as well as share *initial* insights about how these methods generate learning benefits for climate resilience in southern African cities. Many of the methods have been more thoroughly documented in targeted outputs (see

[1] Reflexive learning, in this context, means ongoing, critical reflection.

www.fractal.org.za). The initial insights that are presented in this study require further unpacking.

1.1 Conceptualising learning in FRACTAL

Many different theories and approaches exist across the literature to help understand and design learning, several of which informed the FRACTAL methods. By design, FRACTAL aimed to be transdisciplinary, involving stakeholders outside of academia in knowledge co-production to better understand contextual problems and solutions. The Learning Lab (LL) approach, which was trialed in FRACTAL, aims to support creativity beyond 'business as usual', informed by 'theory U'. Notions of single, double and triple loop learning emerged as team members reflected on previously held assumptions and values, as well as how these were changing. These learning loops were therefore integrated into the FRACTAL learning framework in 2017. The frameworks that informed FRACTAL's approach to learning are briefly described below.

1.1.1 Transdisciplinary co-production

The concepts of transdisciplinarity, co-production and co-exploration were core to FRACTAL since the proposal phase. At the beginning of the project, the team reviewed available literature and defined these terms in relation to one another (see Taylor et al., 2017). The outcomes of this review and definition process are presented below.

- Transdisciplinary research: a process of producing new knowledge [that] integrates the perspectives, practices and knowledge of 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.
- 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.
- Knowledge co-exploration: 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.

Common across these ideas is that "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" (Taylor et al. 2017). Transdisciplinarity insists that research is situated in context, and that societal problems frame research questions instead of academic disciplines (Polk 2014, Klein 2013). Integrating multiple knowledge types also contributes to more contextual, 'socially robust' solutions (Gibbons 1999, Nowotny et al. 2001, Hirsch Hadorn 2008, Polk 2015).

1.1.2 Theory U (Otto Scharmer: change management)

Scharmer (2004) describes 'Theory U' as a multi-stakeholder innovation method that helps unlock creativity for all involved, thereby widening options for dealing with complexity and change. Scharmer describes the process along a 'U' shape (hence the name) representing sequential steps of listening and interpreting. Importantly, learning to listen more meaningfully, and ultimately differently, is at the core of Theory U as this supports emergence and imagining alternative futures that would not otherwise be imagined (Scharmer, 2012). These four levels of listening and interpretation, as well as the outcomes associated with different ways of listening, are represented in the diagram below.

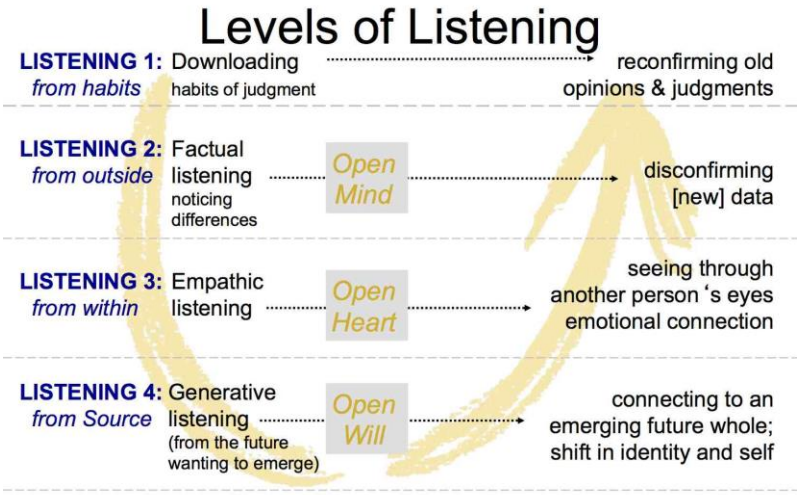

Figure 1. Four stages of listening in Theory U (available at: https://collaborativeresolutionproject.com/2018/08/26/4-levels-of-awareness/)

Scharmer argues that people generally listen and interpret through level 1 (i.e. observations confirm existing ideas and frameworks) or level 2 (i.e. observations update ideas or frameworks), particularly within the confines of academic disciplines and paradigms. The Theory U approach supports listening stages 3 and 4 to deal with problems that are steeped in uncertainty, and with strong social influences and outcomes, such as the impacts of climate change. Listening stage 3 allows one to better understand perspectives of others

while listening stage 4, in particular, allows one to open up to future, better, potential possibilities that are outside of the realm of the 'usual'. Through listening stage 4, participants should strive to be directed by future possibilities as well as past observations and understandings. Theory U provided the founding principles for FRACTAL LLs (Arrighi et al. 2016); the team aimed to create safe spaces that supported empathetic and generative listening to imagine different futures for ongoing problems that might be exacerbated by climate change (i.e. breaking away from the norm).

1.1.3 Single, double and triple loop learning

Argyris and Schon (1978) originally put forward the idea of three learning loops that describe depth of experiences: single, double and triple. While single loop learning refers to detecting errors and implementing changes to correct these (e.g. according to protocols), double loop learning involves reflecting on and possibly changing the learning assumptions or processes (e.g. updating protocols). When comparing the two, one might ask the following questions: in a state of single-loop learning "are we doing things right?" while in double loop learning, one might ask "are we doing the right things?". The third loop of learning relates to shifts in *how* we reflect, learn and adjust; it therefore involves a much more fundamental shift than the first and second loops of learning (Schauppenlehner-Kloyber and Penker, 2015). The loops of learning are illustrated in the figure below.

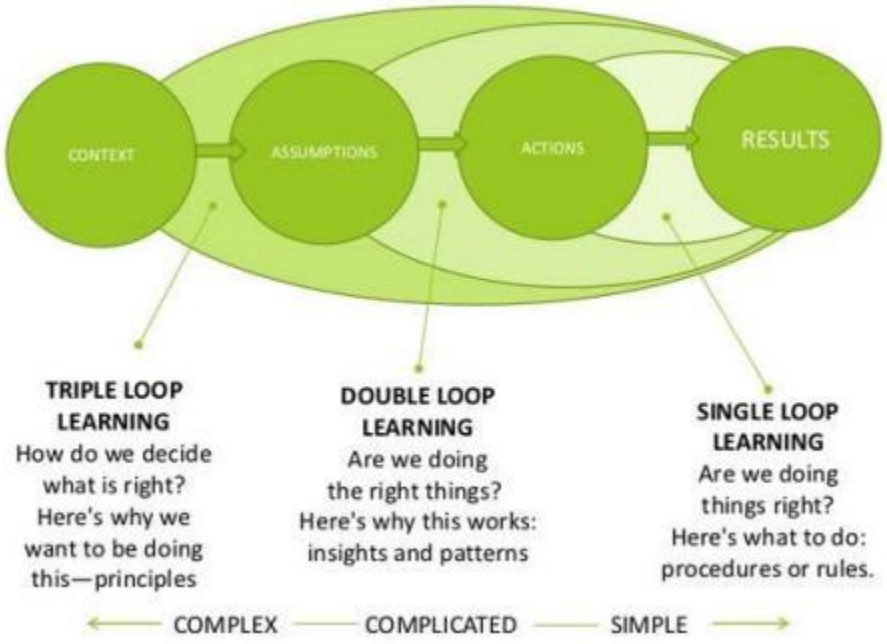

Figure 2. Loops of learning (available at: https://markholmgren.com/2014/05/16/becoming-a-learning-organization-part-one/)

Differences between single, double and triple loop learning emerged through FRACTAL as team members began to critically reflect on decision processes in southern African cities, how research-into-use generally unfolds, as well as changes in assumptions associated with these processes.

1.2 Operationalising learning in FRACTAL

One of FRACTAL's strategic objectives, at the proposal phase, was to *co-design transdisciplinary processes and tools to enhance integration of climate knowledge into decision making in real-world contexts*. Another strong learning aim articulated in the proposal was to *design and engage in a transdisciplinary learning and reflection process, and so enhance the iterative nature of the research process and further develop co-exploration approaches*.

A FRACTAL learning framework was developed and implemented in 2017 to consolidate the underlying learning theories (described above) and provide guidance for supporting and documenting learning. The framework acknowledged that learning will likely take place at multiple scales (e.g. individual, project and organisational). The overall aim of the framework was to "support and facilitate the transdisciplinary co-production of new knowledge for resilient development of cities in southern Africa" (McClure & Koelle, 2017). This aim was to be realised through two main objectives, namely: i) provide a framework that guides the collaborative learning process within the FRACTAL team (including partners and stakeholders); and ii) enable learning that transforms theory and practice for generating and using climate information.

The activities and objectives described in the FRACTAL learning framework supported the reflexive learning spaces, in which empirical data for this study were generated (at various scales). These data are described in more detail in the methodology section of this paper.

2. Aim of the study

The main aim of this study was to consolidate and document the full range of inclusive, participatory, contextual, reflexive learning methods that were implemented in FRACTAL, based on empirical evidence, as well as share initial insights about learning benefits associated with these methods, relevant to climate resilience in southern African cities.

3. Research methodology

3.1 Data collection

Spaces were created to reflect on learning methods throughout FRACTAL, in which data on learnings were generated (see table in Annex A). Most FRACTAL engagements took place in three case study cities in the first phase of the project, namely Lusaka, Maputo and Windhoek[2]. Much of the data generated therefore relates to findings from these cities. At the time of the study, one-on-one interviews were undertaken with stakeholders from Lusaka and Windhoek, allowing for deeper reflection of learning with stakeholders involved in methods in these cities. Lusaka and Windhoek are therefore considered main case study cities.

3.2 Data analysis

Data generated in learning spaces were collated and analysed using an inductive approach[3]. The main themes presented in the "Aim and objectives of the study" section above provided the basis for provisional codes (Saldana, 2013), namely: methods implemented, learning benefits stemming from these methods, as well as how these relate to climate resilience in southern African cities. After initial coding, data were analysed again and organised to surface themes within and between these overarching categories.

This study was strongly influenced by the role of the lead author as the project coordinator in FRACTAL. In this role, the lead author attended many events across the case study cities, supported governance arrangements and administration of project activities, contributed to research and developed close relationships with project partners involved.

4. Findings

[2] The extension phase of the project will focus on inclusive, participatory, contextual, reflexive learning methods in Blantyre, Gaborone and Harare. Although activities were implemented in these cities in the first phase, learning data were not actively generated and stored.

[3] In other words, a 'bottom-up' approach, allowing for themes to emerge instead of testing hypothesis according to a theory or framework (see Trochim, 2006 available at: https://socialresearchmethods.net/kb/dedind.php)

4.1 What learning methods have been tested in FRACTAL?

"it was by design, because you know how most workshops are; you will have the presenter here and he will do his presentation and we ask questions, then he sits and another presenter gets up and it's the same. These ones were very different. They were very involving; you would act out things, you would do posters, creating your future of your city. Somehow, you're part of the process and what's going on; you are not sitting passively" (SSI9, 2019)

Inclusive, participatory, contextual, reflexive learning methods involved engagement across more than 60 different stakeholder groups in Blantyre, Durban, Cape Town, Gaborone, Harare, Johannesburg, Lusaka, Maputo and Windhoek. These processes included social science researchers, climate scientists, impact modellers, human geographers, local municipality, national government, NGOs, civil society organisations, development aid groups, youth groups etc. (RSFP, 2019). An overview of methods that were implemented in different cities is presented in the table below.

Several management and coordination approaches also supported learning within and across cities. For example, research 'clusters' were established near the beginning of FRACTAL to plan and implement research tasks and to increase work across instead of within disciplinary silos. Activities within these clusters were coordinated by cluster co-chairs from different organisations according to workplans and, importantly, FRACTAL team members were free to attend any of the cluster meetings[4]. These clusters met frequently (e.g. monthly) to review and manage workplans adaptively (McClure, 2017).

As learning processes gained momentum in case study cities, specific task teams were established to drive these, as well as design, organise and facilitate events. Task teams were established for core case study cities; Lusaka, Maputo and Windhoek, while a fourth was established to support activities within and across Blantyre, Gaborone and Harare. Task teams were not set up for self-funded cities[5]. These teams comprised *inter alia* the local Principal Investigator (PI), the city focal point, the Embedded Researcher (see below for more information on the Embedded Researcher) and anyone else who was interested in activities in that particular city. Task Teams did not meet as frequently as research clusters but planning within these groups increased in intensity and frequency before each event in cities.

[4] Information about meetings was shared on a bi-weekly basis.
[5] For more information on the structure of FRACTAL, visit www.fractal.org.za

4.1.1 Learning Labs

"I liked the format of engagement; the manner and diversity of presentations; the ideas, topics and activities were so inspiring. I learned more than I would in school. FRACTAL is for me, transformative" (RLL-W, 2019)

Learning Labs (LLs) anchored city learning processes and created spaces for many of the methods described in this study. Five LLs took place in Lusaka, while four were implemented in both Maputo and Windhoek. LLs are facilitated events that bring together a broad range of stakeholders to constructively engage with complex 'burning issues' (Arrighi et al. 2016). Considering the human-centred nature of these problems, LLs explicitly integrated the experiences, emotions, identities and values of people living in the city contexts (IPCC, 2018). At the core of these labs is the objective to "try to solve a complex problem through innovative solutions requiring stakeholders to explore it from various angles" (Arrighi et al. 2016). Although the design of LLs was shaped by the principles and theories described in Section 1.1 above (most notably Theory U), it is important to note that the team held them loosely during the project.

LLs provided the space for current, contextual issues in cities to be identified and collaboratively explored. Aspects of these issues that were explored across all cities included decision processes, governance arrangements and climate-related sensitivities. Several methods were also implemented with a forward-looking perspective; to explore solutions and the potential to use climate change information in planning (LLR-L1-LL5, 2016-2018; LLR-M1-M4, 2017-2019; LLR-W1-W4, 2017-2019). The evolution of the content covered in the LLs and the activities implemented were emergent and iterative; this was an important feature of the LLs as it allowed the direction to be guided by lessons from previous LLs (also in other cities), as well as local contextual needs (SSI7, 2019; SSI8, 2019; SSI17, 2019; SSI18, 2019). Some participants of labs read widely between labs to prepare themselves as they were not sure what content was going to be covered (SSI7, 2019). Reflection sessions were hosted with the broader FRACTAL team after each LL to provide an opportunity for all to learn about the successes and challenges of labs in cities, as well as to take ideas and lessons forward in the design of future labs.

To initiate and anchor the city learning process in each city, 'burning issues' were selected by participants in the first LL; these were issues that were being faced by city residents and were likely to get worse under conditions of climate change. The burning issues that were collectively decided by participants in the first labs are described below.

- Lusaka: peri-urban water issues, namely water supply, flooding and sanitation

- Maputo: potable water, followed by drainage and sanitation
- Windhoek: Water availability in broader Windhoek, and services in informal settlements

For an example of a learning lab process, see this article and video on learning labs that were implemented in Windhoek.

4.1.2 Knowledge sharing across LL participants

LLs and other learning methods included many knowledge sharing sessions to gain a deeper understanding of the burning issues described above, as well as interventions that were already being implemented. The format and content of these sessions depended on the needs that emerged. Much of this knowledge was shared by people who were living and working in case study cities, which was complemented by academic knowledge shared by researchers. For example, a representative from the City of Windhoek presented on "climate-related challenges and opportunities in the city of Windhoek" at the first LL in 2017 (LLR-W1, 2017), a representative from the Ministry of Public Works, Housing and Water Resources presented on the National Water Resource Management Plan in the last LL in Maputo (LLR-M4, 2019) and a representative from the Lusaka Water Security Initiative presented on the use of pit latrines in informal settlements in Lusaka (and their proximity to boreholes) at the first LL in Lusaka (LLR-L1, 2016).

4.1.3 "systems" modeling

The FRACTAL proposal included intentions to generate city-region system models as outputs that might contribute to identifying thresholds related to climate sensitivities. This idea fell away as work started in cities and team members realised that the process of collectively describing city-region systems, and the discussions about social and environmental elements related to these (including climate stressors), were more likely to lead to beneficial learning than a quantifiable model output (SSI18, 2019).

'Mess maps' were trialled in Lusaka to unpack the physical (e.g. resource flows, infrastructure, climate) and social (e.g. actors and decisions) elements of the burning issues within the city-systems (or part thereof), as well as the interactions between these, with a view to exploring the impact of climate variability and change. These maps presented a "systems snapshot of a complex situation" (Foresight Canada, 2019), drawn by participants on large sheets of paper in Lusaka, then translated into digital mind maps using Kumu software (Kumu, 2019). Translation into a digital interface in Kumu allowed for many more elements to be represented in the map, and for these elements to be dynamically explored

(see Figure 3 below). Similarly, in Maputo, a particular part of the city system (dam to distribution) was built using materials such as clay, straws and paper (DWM-LL3, 2018). These representations provided a tool for integrating and visualising multiple knowledge types.

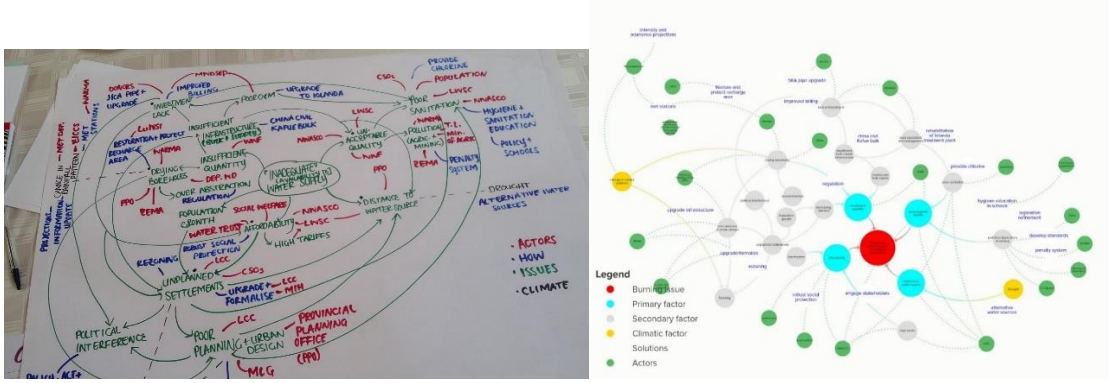

Figure 3: 'Mess map' developed in Lusaka, as well as a Kumu visualisation of the same issue

4.1.4 Field trips

Learning about burning issues in Lusaka and Maputo also occurred through field trips[6]. For example, in Lusaka, participants visited water kiosks in informal settlements and the Kafue river. In Maputo, participants visited the dam that supplies water to the city. These field trips contributed to experiential learning related to the burning issues for both visitors and inhabitants of the city alike (SSI4, 2018). The discussions connected to these field trips, including bilateral conversations between people who might not normally engage with one another as well as group discussions about the field trip and the sites visited, contributed to building relationships and sharing of knowledge.

4.1.5 Games, role plays etc.

Serious games, role plays and talk shows were threaded through the LLs in cities to varying degrees. These activities provided a space for experiential learning that contributed to many different objectives including *inter alia* unpacking relevant issues, grappling with different perspectives, understanding complex phenomena, as well as comparing terminology and concepts (DWM-LL2 2018, DWW-LL3 2018; DWW-LL3, 2018). Serious games and interactive activities also supported the relaxed and fun ambience of the engagements, allowing people to let down their guard (RSLL-L, 2019).

Film and drama were integrated into some of the labs as a way of tracking learning and sharing messages. For example, video messages were produced in Lusaka and Windhoek as

[6] Several participants of LLs in Windhoek attended field trips through related research but the need to include this method as part of the LLs, with the broader set of participants, did not arise.

part of the 'learning lab link'; participants would record a message in a short video for those taking part in the next learning lab in a different city (RSLL-L, 2019). Several activities and reflections from learning labs were also captured on video as a way of sharing insights and experiences with those who could not take part in the labs (e.g. see .

4.1.6 City-to-city exchanges

Lessons and ideas from across the region were brought into the LLs through exchanges of people and concepts from one FRACTAL city to another. For example, the day zero campaign in Cape Town was discussed in Lusaka and Maputo, and participants imagined what a day zero in their city might look like (DWM-LL2, 2018; DWL-LL3, 2018). Lusaka and Windhoek delegates visited Maputo, Durban and Gaborone delegates visited Windhoek, and an exchange took place between Harare and Lusaka[7]. In all cases, visiting delegates shared experiences from their home cities, usually through the format of a talk show or similar and participants were provided an opportunity to ask questions (DWW-LL3, 2019; DWM-LL4, 2019). A "learning lab link" was introduced in the third year of the project, which saw gifts, ideas and messages spread from one lab to the next in another city. This resulted in the culmination of an artwork from participants across Lusaka, Maputo and Windhoek and helped develop a sense of connectivity across the FRACTAL cities (see Figure 4 below). The Durban-Lusaka exchange resulted in Lusaka participants signing the Durban Adaptation Charter (DAC), which "commits Local Governments to local climate action in their jurisdiction that will assist their communities to respond to and cope with climate change risks thereby reducing vulnerability"[8].

[7] The delegate team consisted of at least one city official, the project PI from the cities and the embedded researchers

[8] https://www.durbanadaptationcharter.org/about-the-charter

Figure 4. Learning Lab link

4.1.7 Climate Risk Narratives and visioning processes

Climate-related considerations or sensitives were explored during the process of unpacking 'burning issues'. The most common method implemented for this purpose across the case study cities was co-production of Climate Risk Narratives (CRNs), which is described below.

A narrative is essentially a story. In FRACTAL, CRNs have been developed by integrating different knowledge types to co-produce stories for cities with many different stakeholders. Stories are co-produced considering the full range of plausible climate futures, thereby accounting for uncertainty. CRNs include academic knowledge such as climate science and hydrology, local knowledge about decision priorities and processes, as well as different perspectives about potential climate impacts. Ideally, knowledge from important societal representatives, such as local community organisations and the private sector, is also involved in developing these stories. CRNs are subject to change over time as physical (including climate), social and ecological processes unfold, as well as the feedbacks between these. CRNs should therefore be iterated in an ongoing dialogue between the multiple groups of stakeholders described above.

CRNs were developed in seven of the nine FRACTAL cities, with another attempt in Durban as a self-funded city[9] (DTLW2, 2018). In Lusaka, Maputo and Windhoek, the first drafts were produced by climate scientists, after which they were presented as texts to participants in cities and iterated to include contextual knowledge about socio-economic impacts. These were eventually converted into infographics in some cities (e.g. see Figure 5) and into skits in Lusaka (DWL-LL5 2018). In Blantyre, Gaborone and Harare, stakeholders from these cities developed the first drafts of textual socio-economic narratives for the future, into which climate scientists attempted to weave climate change information (DTLW2, 2018). CRNs helped participants explore different climate futures and consider how climate change might exacerbate existing and future developmental challenges (DTLW2, 2018; SSI9, 2019; SSI14, 2019; SSI21, 2019; SSI216, 2019; SSI31, 2019). Participants of the LLs (and other engagements in Blantyre, Gaborone and Harare) contributed to shaping the narratives as more and more contextual knowledge was integrated with each iteration. The benefits and challenges associated with the two different approaches require further unpacking and testing to understand which is more effective, or effective in particular contexts.

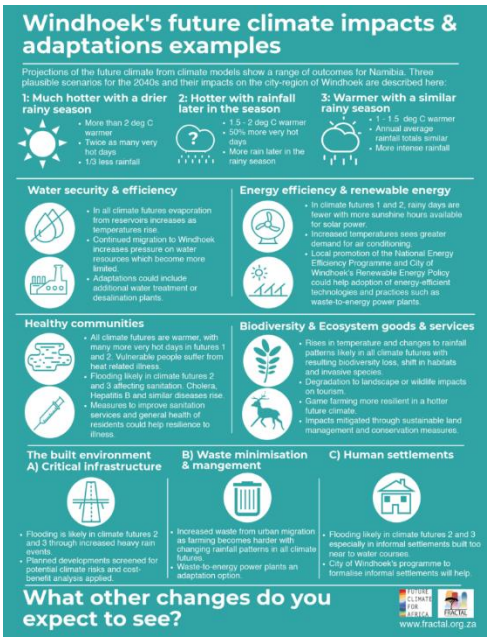

Figure 5. Windhoek CRNs

CRNs provided one mechanism of envisioning a future of FRACTAL case study cities, as well as connecting current actions with these narratives. Other future visioning exercises that were employed in the LLs were the 'Three Horizons' approach used in the Maputo (Scott,

[9] The nature and format of the city learning process in Durban was not conducive to continued development of the narratives, see http://www.fractal.org.za/wp-content/uploads/2020/03/IS8-Working-across-knowledge-types.pdf

pers. comm., 2019) and the 'stepping stones to the future' exercise in Lusaka (DWL-LL3) (see figure below).

Figure 6. LL participant partaking in the Three Horizons activity

4.1.8 Distillation sessions

Methods that allowed participants to better understand case study cities and think about the future climate, as described above, paved the way for participatory interrogation of how climate information might add value to decision making in southern African cities. Such activities ranged from fairly light discussions about existing information (e.g. Cape Towns "big six dam monitor"[10] and the national climate change profiles for African countries[11] in Maputo) (DWM-LL3, 2018; DWM-LL4, 2019) to methods that allowed 'epistemic access' to climate science for all participants at the labs (Soal, 2019). All discussions that focused on exploring the role of climate information in decision making provided time for participants of LLs to interrogate the information and ask questions.

Climate change information was deeply explored with stakeholders through 'distillation sessions' in the final LLs in Lusaka (LL5) and Windhoek (LL4) (DWL-LL5, 2018; DWW-LL4; 2019). 'Distillation', meaning the "the extraction of the essential meaning or most important aspects of something" (Oxford English Dictionary) has been a core concept for FRACTAL since the proposal phase. Distillation sessions supported very honest discussions between the

[10] http://cip.csag.uct.ac.za/monitoring/bigsix.html

[11] that were produced by CSAG through a different project: https://zivahub.uct.ac.za/articles/National_Climate_Change_Profiles_Enhancing_the_capacity_of_African_countries_to_use_climate_information_to_inform_decision_making/7946000. Also shown in a Maputo LL.

climate scientists and participants living in the cities about the ways in which climate information is produced, or could be better produced, based on specific needs.

Although the overarching aims for the distillation sessions were the same (to interrogate climate evidence relative to decision making with stakeholders in the LLs), the framing of the discussions differed in the two cities. In Lusaka, LL participants were tasked with designing a hypothetical project to support water security and were asked to conceptualise a proposal including a request for climate change information; they were to explain the specific climate change information they requested and why they thought this information was important. After these requests were posed, the FRACTAL climate scientists described the data, models and methods that they might use, the analyses they would likely run and the assumptions they would need to make to produce the requested information. LL participants were free to ask questions, at any stage of the discussion, about the process of producing the information (DWL-LL5, 2018).

In Windhoek, climate change information was presented on three graphs of varying complexity, which were handed out to groups of participants at the last LL. Participants spent time discussing the graphs and developed a list of criticisms, questions and requests for tweaking the information so that it might be more useful (DWW-LL4, 2019). The conversation around these 'opened up' the science, supporting access to climate information for all participants, as well as a deeper understanding (Soal, 2019).

4.1.9 Co-production of tangible outputs

Several tangible documents, products and drawings were used as a way of surfacing perspectives and priorities, integrating existing knowledge and capturing new knowledge emerging within the LLs. Policy briefs were co-produced in Lusaka listing suggestions to manage the burning issues related to water security, including a climate perspective (DLW-LL3 2017). FRACTAL also supported the development of the Integrated Climate Change Strategy and Action Plan (ICCSAP) in Windhoek (DWW-LL2 2017). The development of these documents anchored the LL processes in Lusaka and Windhoek and involved participants. Several TD methods also allowed for participants of labs to explicitly engage with and influence outputs from disciplinary or interdisciplinary research, for example governance arrangements in Maputo and the Water Evaluation and Planning (WEAP) modeling and decision scaling activity in Lusaka (DWL-LL3; SSI12, 2019).

4.1.10 Social events

Considering the importance of relationships and trust for open dialogue and co-producing knowledge in FRACTAL cities, social engagements and informal discussions before, between and after LLs contributed greatly to the learning processes (SSI4, 2018; DWL-LL1, 2016). LLs were often hosted outside of the city with the opportunity for people to spend a night away from the 'hustle and bustle' of everyday life and engage with people that they might not normally spend time with (SSI4, 2019). These informal discussions enabled connections between stakeholder groups and enquiry around topics that more formal spaces did not allow. Many of the informal discussions revolved around what had been discussed during the LLs, allowing for more informal dialogue around the burning issues, climate change, climate information etc.

4.1.11 City dialogues

City dialogues were envisaged, at the beginning of FRACTAL, as smaller, more targeted engagements relevant to the larger city learning processes (anchored by the LLs). The original idea was to include a variety of creative or traditional formats such as talks, workshops, art exhibitions, meetings etc. to help explore burning issues. However, as the project panned out, much more emphasis was placed on the larger LLs at the cost of fewer dialogues (SSI7, 2019). The few dialogues that took place were generally implemented in a more traditional format of small, targeted meetings, covering topics related to water management, governance and energy. They were useful in evolving the discussions in cities but did not fulfil the initial intention of these platforms (SSI7, 2019). City dialogues also took the format of high-level breakfast meetings in Lusaka (DWL-LL2, 2018). These breakfast meetings were designed so that busy decision makers and politicians could easily receive information from and provide input to FRACTAL. The design and content of these dialogues were informed by LL processes, and outcomes of dialogues were presented back to the broader group of LL participants. The dialogues contributed to a sense of consistency or FRACTAL presence within cities.

4.1.12 Embedded Researcher

The Embedded Researcher (ER) approach was implemented in several FRACTAL cities, drawing on lessons from Mistra Urban Futures (see Hewitson et al. 2014) (SSI1, 2018; RSFP, 2019). These researchers essentially provided a consistent link between academia and decision making in cities. ERs were contracted by universities but spent much of their time in local municipalities building an understanding of the context and seeking opportunities to connect climate-related research with decision making processes. As the project progressed,

the ERs in many cities provided guidance on activities and contributed hugely to the city learning process.

A more thorough analysis of the ER approach has been undertaken and is shared through a FRACTAL working paper (Pretorius et al., 2019).

4.1.13 Capacity development activities

Although developing capacity of both decision makers and researchers was included as an explicit objective in the FRACTAL proposal, methods and outcomes of capacity development activities were not designed from the outset[12]. The dialogic approach of the LLs was key for developing the capacity for all involved[13]. Activities were also implemented to support capacity development outside of the LLs as needs arose. For example, introductory climate change training was run with newly elected councillors in Lusaka, the Climate Capacity Diagnosis & Development (CaDD) tool was run with decision makers in the water sector in Lusaka and Windhoek (DWW-LL2 2017; SSI31, 2019) and technicians were trained on issues of climate change and information in Maputo (DWM-LL2, 2018). Decision makers in Windhoek requested a 'transformational leadership for climate change' workshop during one of the LLs, which was implemented with two groups of people, including the Strategic Executives for Economic Development and Community Services (Ipinge, 2018; DWW-LL2 2017).

Several participants of learning processes in Blantyre, Gaborone, Harare, Lusaka, Maputo and Windhoek also took part in the annual CSAG Winterschool. The Winterschool "aims to take participants through the full spectrum of climate and climate change related topics"[14] and therefore provided a good foundation for many of the more in-depth and critical discussions related to the value of climate change information.

The sequence of discussions, trainings and activities within and outside of the labs allowed for understandings to develop as appropriate and necessary. The distillation activities, for example, were included at the end of the city learning processes once decision makers had a better understanding of the nature of climate information and associated terminology, while the climate scientists understood the city contexts better.

[12] For capacity development ideas that were included in the proposal, see Hewitson et al., 2014.
[13] A dialogic approach to learning involves discussion among one or more participants, all contributing equally to learning. This differs from a traditional didactic approach, which involves one person or group teaching (imparting knowledge) on other groups. See Racionero and Vallis, 2007.
[14] http://www.csag.uct.ac.za/ws-courseoutline/

4.2 What are the main learnings from these methods, relevant to climate resilience in southern African cities?

"The process stretched my knowledge and imagination levels; a part of me was extended. True learning happened because of the process" (RSLL-L, 2018)

Through discipline-specific research and the approaches described in the introduction, FRACTAL contributed a wealth of evidence, knowledge and lessons on issues related to climate risks in southern African cities, as well as responses to these issues. The findings presented in this section relate to the learnings that were generated through the activities described in Section 4.1. Findings from traditional disciplinary, interdisciplinary and cross-disciplinary research methods are not included in this section (e.g. governance research or core climate science). It is however, acknowledged that many of the findings from disciplinary research were brought into the participatory methods, either explicitly through presentations and information sharing sessions (see section on methods that were implemented), or implicitly through people who were involved in both disciplinary and transdisciplinary processes in parallel. Without these parallel disciplinary research processes, inclusive, participatory, collaborative learning would not have been as rich. The methods described above allowed for sharing of existing knowledge across paradigms, disciplines and boundaries, as well as co-producing new knowledge.

4.2.1 A richer understanding of Southern African city-regions

"I am seeing information that was not previously being documented, going beyond the formal structures and systems we know like those represented by organograms etc. And the analysis of this knowledge and information coming out of these engagements is now trying to understand how climate information can be infused into these unknown processes in the city. So, I think new knowledge is being produced, across the cities" (SSI1, 2018)

Much knowledge about southern African city regions was generated through the methods described in the section above (DTLW1, 2018). An important factor in producing this knowledge was the wide variety of stakeholders involved in city learning processes, collaboratively unpacking 'burning issues' that are currently being experienced and will likely be exacerbated by climate change, as well as thinking about how climate change information might be usefully integrated into decisions. Multiple knowledge types helped to deepen understanding of the variety of both climate and non-climate stressors that influence southern African city systems (DTLW1, 2018; RLL-W, 2019; SSI23, 2019). The 'mess map' that was produced and iterated in Lusaka provides a good example of many knowledge types

coming together to produce a rich, multi-dimensional understanding of the city-region (see below).

Figure 7. Lusaka mess map produced by participants

Working across nine southern Africa cities, each with their own set of characteristics, brought a lot of logistical challenges to FRACTAL. The learning potential across these cities was, however, supported by the depth and breadth of experiences (SSI6, 2018). Knowledge was generated about the similarities and differences in climate- and water-related problems as well as solutions across cities of southern Africa through several methods described in Section 4.1 (see Ndebele-Murisa, 2020). Exchanges, in particular, allowed for FRACTAL participants to share strategies that are being employed effectively to deal with the aforementioned challenges, e.g. accessing international climate finance or building technologies such as ecosan toilets and water reclamation plants (DWRM-LL3, 2018; RSLL-M3, 2019).

4.2.2 Understanding climate risk within and across southern African cities

Many participants involved in FRACTAL city learning processes gained extensive knowledge about climate-related risks in their cities through the methods described above, including technicians, policy makers, commissioners, as well as researchers who previously had not worked on such issues (ALS1, 2017; RSFP, 2019; LLR-L2, 2017). This includes more knowledge about *inter alia* the range of future projections for the southern African region, weather and climate terminology, southern African climate processes, methods for producing and presenting climate information, the potential impacts of climate change in case study cities, as well as approaches for accessing relevant information to support decision making (ALS1,

2017, LLR-W3, 2018; RSLL-W, 2019; RSLL-L, 2018; DWM-LL3, 2018; SSI3, 2018). Several participants of LLs attribute most of what they know about climate change to the FRACTAL project (ALS1, 2017; SSI9, 2019; SSI13, 2019; SSI14, 2019).

Many participants of LLs had engaged with climate change information before FRACTAL but had not been able to 'connect' with the phenomenon or the science in a meaningful way to fully understand and translate the information into their own context (RSLL-W, 209; RSLL-L, 2018; SSI9, 2019; SSI14, 2019). Participants in both Lusaka and Windhoek described seeing the concept of climate change presented in the media before involvement in FRACTAL, while not knowing what this meant for their city or for them at a personal level (RSLL-W, 2019; SSI9, 2019; SSI31, 2019). The methods described in the section above, particularly the CRNs, provided opportunities for stakeholders to 'localise' the abstract notion of climate change to their contexts (RLL-W, 2019; SSI9, 2019; SSI26, 2019).

4.2.3 Understanding the value of climate change information in planning for southern African cities

Challenges associated with planning and action for climate change in case study cities were surfaced through engagements. Limited internal financial resources were often mentioned as a major barrier to implementing such actions (SSI9, 2019; SSI10, 2019; SSI17, 2019). The disconnect within and between scales of governance also surfaced as a hindrance (DTLW1, 2018; ALS2, 2018; DWM-LL2, 2018; RSLL-M, 2019) as it undermines efforts for tackling multi-sectoral, multi-scalar issues that cut across government agendas such as climate change. Similar to the knowledge about the complexity of the city systems, this was learned by all participants of the LLs including visitors and those working and living in the cities (SSI4, 2018).

Creating general awareness about climate risks was much easier than surfacing the value of climate change information for planning in case study cities. Review of literature and engagements in several case study cities pointed to the fact that (at least some) information on climate change, in the form of journals, reports and even government plans does exist (i.e. it has been produced) (DTLW1, 2018; SSI7, 2019). This finding sparked critical reflection within the team on why such information is not being integrated into decision making (SSI7, 2019), and helped guide future LL plans.

Several barriers to integrating climate change information into planning were identified through the methods described above including *inter alia*: i) the temporal disconnect

between current decision making processes and future climate change information[15] (SSI9, 2019); ii) the urgency of development issues and socio-economic priorities compared with planning for the future and consequently, the human and financial resources directed at this (DWM-LL2 2018; SSI10, 2019); iii) the inaccessible or confusing format of much climate information that is readily available[16]; and iv) the scalar disconnect between climate change information and planning for cities, both in terms of understanding climate change impacts within the city, as well as thinking about resilience targets (e.g. do we need climate change information that supports resilience of particular infrastructure or an entire city system?) (ALS2, 2018).

The FRACTAL team learned that few opportunities existed for integrating climate change information into decision making processes in southern African cities for many reasons, including those described above (DTLW1, 2018). The widespread notion of 'finding entry points' for such information was therefore challenged within FRACTAL. Team members instead worked with decision makers and other citizens to co-create entry points for climate change information in decision and planning processes. Before these entry points could be co-created, contextual climate change risks needed to be explored and the value of climate change information in specific contexts needed to be interrogated with participants of LLs. This move from "co-exploring to find entry points" to "co-producing and creating entry points" is one of FRACTAL's major conceptual developments. In line with this conceptual development is the idea that evidence and decision making for climate change resilience need to become entangled or enmeshed, instead of expecting climate information to fit neatly into existing decision-making processes (Taylor, in McClure, 2019).

Conversations about climate change information that allowed for interrogation by participants of LLs (i.e. distillation and CRNs) increased understanding of the types of climate information that might add value in the decision contexts of southern African cities (SSI11, 2019; SSI13, 2019; SSI25, 2019; SSI26, 2019). The pre-existing belief that more core climate science should be produced to aid planning in African cities was challenged, with a shift towards focusing more on effective ways of brining climate change considerations into conversations about development in FRACTAL cities (SSI7, 2018). The FRACTAL team learned that in some cases, existing climate information is adequate but needs to be repackaged or better communicated to connect to the decision space (SSI7, 2018). For example, stakeholders in some cities expressed preferences for using CRNs with positive framings (i.e.

[15] The FCFA programme was framed to generate science on future climate changes around the year 2040 and integrate these into planning.
[16] This was already well known before FRACTAL engagements

if climate resilience actions are implemented) instead of describing negative outcomes (DTLW2, 2018). Through a conversation in Windhoek, climate scientists realised that the climate change information they had presented might be useful but the thresholds that they chose to represent were not. Government representatives working at the water reclamation plant were interested in one temperature threshold, while those working on maintaining manholes were interested in a different threshold (DWW-LL3, 2018; DWW-L4, 2019). In Lusaka, conversations in the LLs led to more useful framing for climate change information related to return periods for floods (SSI11, 2019; SSI20, 2019).

Climate scientists involved in collaborative, dialogic methods seemed to gain 'literacy' in terms of asking questions that would support development of more useful climate change information, as well as tweaking information for a particular context or set of priorities (SSI11, 2019; SSI12, 2019; SSI18, 2019). These methods increased the ability of scientists to work alongside decision makers and produce more relevant information (SSI6, 2018).

Through activities that sought to increase 'epistemic access' to climate science, participants of LLs also gained knowledge about the processes involved in producing climate change information. For example, decisions and assumptions made by climate scientists to produce information, which are generally not discussed, were shared and interrogated. The methods described above supported 'freer', more trusting engagements with climate scientists on issues of uncertainty and, in Lusaka and Windhoek, participants collaboratively explored how uncertainty is often traded for risk of not planning for a different potential climate future (SSI13, 2019; DWW-L4, 2019). Participants from Lusaka and Windhoek described how they felt more comfortable with the uncertainty associated with the climate future of their cities and are more likely to consider a spectrum of impacts when planning (DTLW3, 2018; SSI9, 2019; RSLL-L, 2018; SSI26 2019).

The timing of the distillation sessions (i.e. sessions for interrogating climate change information) is noteworthy; in FRACTAL, trust had been built among the group (SSI8, 2019), scientists were also better placed to present information in a way that connected to the context (LLR-L5, 2018) and participants from the cities had engaged, to a degree, with climate variability and change concepts. Participants from cities were better equipped to ask questions and interrogate the information than they might have been nearer the beginning of the city learning process (LLR-L5, 2018; SSI8, 2019; SSI20, 2019).

[climate scientist talking about the distillation session] "I suspect it's down to a lot of the groundwork that FRACTAL laid for me. People in the room had awareness of what a learning lab looked like and what we were trying to promote in that space" (SSI20, 2019)

4.2.4 Southern ownership of climate-related challenges and responses in cities

Participants involved in the collaborative, dialogic methods were provided an opportunity to better connect with the abstract notion of climate change, as well as what this means for their city. This connection instilled ownership of the responses for many at an institutional and personal level (RLL-L, 2019; RLL-W, 2019; RLL-M, 2019). The forward-looking planning and visioning exercises, in particular, allowed participants of LLs to look into and imagine a future that might help drive current action and planning linked to their existing mandates (SSI5, 2019; SSI9, 2019; SSI21, 2019; SSI23, 2019; SSI25, 2019).

Not only were participants able to connect to climate-related problems and solutions in their own cities, many expressed gratitude for hearing about solutions from other southern African cities through the exchange mechanisms. For example, the City of Windhoek has worked towards innovative and cutting-edge technologies to solve their water scarcity issues; these lessons were shared with participants in Maputo. Stakeholders attending LLs in Lusaka, Maputo and Windhoek heard about ways in which Cape Town residents avoided day zero. Sharing such lessons inspired hope for responding to climate change (RLL-M, 2019).

4.2.5 Developing relational capacities

"And that, to me, has been one of the reasons why people have stayed engaged with the process. They are able to ask questions that they cannot solve. And there will be someone in the room who can do that, who can put some answers on the table or to facilitate a process for all of us to learn. That is the contribution of the co-production process" (SSI3, 2018)

Many of the approaches described in Section 4.1 differ from the more traditional methods of capacity development or research-into-use processes during which stakeholders are expected to passively 'receive' information from researchers (SSI8, 2019; SSI9, 2019). Representatives of different urban groups (government, NGOs etc.) shared information about their mandates and objectives, relevant to the ways the FRACTAL cities function, are governed and are sensitive to climate variability and change (RLL-W, 2019; SSI9, 2019). In the case of Windhoek, even the finance department began to understand their role in the climate change agenda (DWW-LL3, 2018). These methods supported an appreciation for the diversity

of objectives and knowledge types across the broader group of participants. For example, representatives from Lusaka City Council reflected on the fact that they now have a better understanding of the "wealth of knowledge" of their colleagues and can now pick up the phone and request information; this type of exchange was not common before FRACTAL (RSLL, 2018; SSI9, 2019; SSI13, 2019). Team members commented on the shift in LL processes in Lusaka and Maputo; from a stance of 'finger pointing' to collaborative framing and inquiry to solve the issues (RSLL-L, 2018; RSLL-M, 2019). Visioning exercises and the CRNs, allowed people to connect their personal and work roles to solutions and build accountability (LLR-L3, 2017; LLR-W1, 2017; RSLL-L, 2018; RSLL-M, 2019). Several participants have expressed an appreciation for approaching issues of climate risk in southern African cities in a more collaborative way and are hoping to carry this forward through various avenues of work (ALS2, 2018; SSI11, 2019; RSLL-L, 2018; RSLL-M, 2019).

An important relationship that has been strengthened through FRACTAL is that between the local authorities and the universities (SSI8, 2019; SSI25, 2019). Because of their very different modes of working and mandates, these two organisations complement each other well, especially for those university partners who are becoming increasingly interested in applied research (SSI16, 2019). While researchers have more space and time for reflection and analysis, authorities need to make quick decisions on an ongoing basis, preferably using evidence that academic institutions might provide (SSI9, 2019; SSI10, 2019).

4.2.6 Getting better at inclusive, collaborative and participatory approaches for dealing with complex issues such as climate risks in southern African cities

Researchers and participants of labs in the cities have generated knowledge on the methods and processes, as well as the benefits, of inter- and trans-disciplinary research for co-producing knowledge on climate risks that supports decision making (ALS1, 2017; DWW-LL3 2018; RLL-W, 2019). Several participants from different backgrounds have used methods and content that they gained through FRACTAL in their own follow-on work (SSI9, 2019; SSI32, 2019; SSI21, 2019; SSI22, 2019; SSI14, 2019). Much of this knowledge was generated by being directly involved in the methods described above.

Several lessons relevant to inclusive, collaborative and participatory approaches for dealing with complex issues such as climate risks in southern African cities that emerged from this study are listed below.

- Emergence, open-endedness and reflexivity are core of learning labs such as those implemented in FRACTAL. This allows for contextual city needs to surface, as defined by participants. (SSI6, 2019; SSI7, 2019; SSI11, 2019)
- The diversity of methods is important. It allows for different voices to emerge and contribute, and for knowledge to be captured in different ways. Different people feel more comfortable sharing information is a variety of ways and a method that appeals to one person might not appeal to another. This diversity also supports connectivity of the range of participants with the issue at hand (e.g. through graphs, narratives, skits and graphics). (SSI7, 2019; SSI10, 2019)
- The size of the group involved in Learning Labs is important; it can be anywhere between 15 and 30 or 35. 40 is the limit. (DWL-LL1, 2017)
- It is important to consider who is in the room; you need to bring the right people together to talk to the desired learning processes and outputs. Continuity of participants should also be strived for, while not excluding those who are interested in taking part. (SSI1, 2018)
- The role of a local coordinator and ER should not be overlooked. The ER was pivotal in organising events and bringing people together. (SSI5, 2018)
- The facilitator also plays a crucial role in holding the process together (SSI7, 2019), and supports the development of energy amongst participants to carry the learning process forward.
- Those involved in the TD methods from other locations (towns, countries etc.) should familiarise themselves with local processes, issues and cultural expectations. (SSI8, 2019)
- Contestations are important for the learning process when dealing with such complex issues, as they are indicative of tensions or anxieties emerging, as well as a variety of different perspectives that might contribute to solutions (DWW-L3, 2018)[17].

FRACTAL team members have reflected on the difficulty of capturing and sharing lessons about inclusive, collaborative and participatory approaches for dealing with complex issues in textual documents or teaching them in a didactic fashion (e.g. lecturing on methods). Capacity to design and implement such methods is best developed by involvement in, or experience of, these processes (SSI6, 2019). This challenge is a serious consideration when attempting to scale methods that aim to distil relevant climate knowledge for decision making in southern African cities.

[17] Several theories of learning include the notion that learning, or change can only happen once contradictions emerge (e.g. Cultural Historical Activity Theory - see Lindley, 2015). Contradictions and contestations do, however, need to be managed adequately.

"quick answers are often requested for burning issues related to the intersection of climate with city decision making; this is a tension that they need to face and manage… There is no magic, silver bullet for these climate change problems so constant exploring is necessary" (DTLW3 2018).

Discussion

The findings from the empirical analysis provide initial insight into the value that inclusive, participatory and reflexive learning processes contribute to support several learning benefits in southern African cities. The learning benefits from these methods are summed up below.

- Connecting agendas to climate change (ownership & agency)
- More holistic understanding of the problem (and complexity)
- Building trust
- Understanding roles that various people play in the climate change agenda
- Know-who (working alongside others to solve problems)
- Interrogation of assumptions and values, as well as the value of (climate change) information
- Co-creating entry points for information
- Producing contextually robust knowledge (more literate in asking questions)
- Creativity & openness (to move beyond 'business-as-usual')
- Gaining knowledge (social and technical)
- Introducing a forward-looking perspective
- Establishing & strengthening relationships
- Establishing channels of communication
- Less anxiety associated with emergence and uncertainty
- 'Landing' the abstract notion of climate change

Transdisciplinary co-production framed the ethics and principles upon which FRACTAL activities were founded. The complexities and uncertainties associated with climate risks in southern African cities were highlighted and explored, which is an explicit objective of transdisciplinary research (Klein, 2013), co-production and co-exploration as detailed in the working paper developed near the beginning of FRACTAL (Taylor et al. 2016).

The loops of learning that were put forward by Argyris and Schon (1978) help to consider different types of learning benefits from several activities. For example, many decision makers who were involved in FRACTAL learning processes activities reframed their understanding of climate-related issues in their cities; as systemic issues towards which various departments or groups of people are already contributing, which indicates 'loop 2 learning' (asking questions similar to "are we doing the right things?"). Climate scientists and other researchers challenged the notion of 'finding entry points' based on experiences and

critical reflection, which also aligns with loop 2 learning. In exploring the value that climate change information does (or does not) add to priority decisions in southern African cities, and critically reflected on the academic knowledge production process, one might argue that some learnings from FRACTAL fall within the realm of 'loop 3' (questioning assumptions).

Theory U provides a useful framework for understanding how creative, reflexive learning activities, which are different from didactic teaching methods or passing on information in the 'producer-user' chain, help people to collaboratively grapple with a complex and emergent issue such as climate risk in southern African cities. The findings presented in Section 4.2 resonate with the concept of moving from listening stages 1 and 2 to stage 3 to collaboratively imagine alternate futures. Many participants commented on a deeper understanding and appreciation for different perspectives of a common problem related to climate risks in their city. Future-oriented visioning exercises helped participants imagine a future that might help drive current action and planning linked to different mandates. The benefits of such forward-looking processes for creativity and influencing action are described by Wartofsky (1973); "The upshot, however, is that the construction of alternative imaginative perceptual modes, freed from the direct representation of ongoing forms of action, and relatively autonomous in this sense, feeds back into actual praxis, as a representation of possibilities which go beyond present actualities" (Wartofsky, 1973, in Edwards 2011).

Activities that encouraged deeper, different listening styles among participants from different groups (with different mandates) also supported relational capacities. Concepts associated with these capacities emerged inductively as some of the most important concepts of FRACTAL. Relational learning benefits are described in transdisciplinary co-production and Theory U literature, but several more specific relational concepts emerged from the analysis, namely concepts of receptivity (Scott and Taylor, 2019), as well as relational expertise, shared knowledge and relational capacity (Edwards, 2017).

The importance of building 'receptivity' through inclusive, participatory, contextual, reflexive learning processes was proposed by Scott and Taylor (2019) towards the end of FRACTAL as a way of; "actively and critically reflecting on one's own knowledge and that offered by others (i.e. recognizing various assumptions and framings). This forms the basis for expanding or enhancing one's ability to make less partial, narrow judgements, and to shift one's practices and actions based on a broader view of the system and what changes are underway and are sought (by individuals, organisations and collectively). As such, receptivity to other frames of reference is in no way passive. Rather it is a stance, a way of engaging, thinking and acting in

relation with others that is open and considered, with a willingness to share, to let go, to take on and arrive at new insights and new ways of thinking and being… integration and extension of urban climate information needs to be done in a way that grows the collective knowledge base and empowers people to act in their various individual capacities and organisational mandates."

Without opportunities for sharing perspectives and deeper listening through the learning processes described in Section 4.1, the receptivity of decision makers to understand the frame of reference of climate scientists would have remained limited, as would the receptivity of researchers to understand and appreciate the decisions and processes that drive urban development in southern African cities. These two stakeholder groups, as well as others that should be involved in planning for climate resilience in cities, are likely to continue talking past one another through traditional, didactic engagements that don't allow people to share relevant knowledge equally.

The concepts of relational expertise and relational capacity, proposed by Edwards (2011), also emerged as important outcomes of deep listening processes. Relational expertise is the ability to *align one's own expertise or knowledge in relation to others* to solve problems and can be closely aligned with 'know-who' instead of 'know-how' (e.g. skills) or 'know- what' (e.g. content). Relational capacity is strongly connected to relational expertise and common knowledge, implying the ability to and affinity for *working alongside others to respond to* complex problems (Edwards, 2017). Relational expertise needs to be built and supported through activities that connect groups of people through longer-term, common goals while recognising and appreciating their differences, such as the LLs.

Common knowledge grows alongside receptivity and relational expertise as the knowledge of the motives or objectives of different groups involved in a task, for all to understand and maximise. This knowledge becomes a 'resource' that can be used to design responses to complex problems that support buy-in and support joint decision making (Edwards, 2017). Edwards (2017) emphasises the fact that this shared knowledge does not emerge spontaneously, instead it is cultivated through activities that: i) recognise and make explicit similar long-term goals across different groups; and ii) reveal specific values and motives, and allow for all to be heard. By building a common knowledge of motives of different organisations, responses can be better designed to accommodate these, even if there are many. This contrasts with trying to facilitate agreement on one common motive across groups that have very different mandates and working objectives. The approach might,

therefore, be more realistic and appropriate when dealing with cross-cutting issues such as climate change.

Conclusion

The FRACTAL team employed a wide variety of inclusive, participatory and reflexive learning methods to co-explore problems and solutions in local development contexts, as well as how climate change might exacerbate these. These methods were loosely guided by transdisciplinary co-production, Theory U and single, double and triple loop learning literature, which help to describe several learning benefits that were experienced in FRACTAL and detailed in this empirical study. For example, gaining a more holistic perspective of complex problems (transdisciplinary co-production), unlocking creativity to imagine an alternative, better future (Theory U) and critically reflecting on assumptions and values (loops of learning). Several additional learning benefits that are not well described in these literatures, however, emerged as some of the most important FRACTAL outcomes, particularly receptivity, relational expertise, relational capacity and common knowledge. Insights into the links between the methods that were implemented, and the learning benefits described have been suggested in this study but require further investigation.

REFERENCES

Argyris, C and Schön, D.A. Organizational Learning: A Theory of Action Perspective. Reading, MA: Addison-Wesley, 1978

Arrighi, J., Koelle, B., Besa, M.C., Spires, M., Kavonic, J., Scott, D., Kadihasanoglu, A., Bharwani, S., Jack. C. 2016. Dialogue for decision-making: unpacking the 'City Learning Lab' approach. FRACTAL working paper. Available online at: http://www.fractal.org.za/wp-content/uploads/2017/03/RCCC-FRACTAL_wps-7-City-Learning-Lab-V4.pdf

Bateson, G. Steps to an ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology. New York: Ballantine Books, 1972

"Distillation" OED Online. Oxford University Press, December 2019.

Edwards, A. 2011. Building common knowledge at the boundaries between professional practices: Relational agency and relational expertise in systems of distributed expertise. *International Journal of Educational Research* (50): 33–39

Edwards, A. Working Relationally in and across Practices: A Cultural-Historical Approach to Collaboration. Cambridge: Cambridge University Press, 2017

Foresight Canada. 2019. Mess Maps and Murals blog. Available online at: https://foresightcanada.com/services/mess-maps-and-murals/

Funtowicz, L.S., & Ravetz, J. 1994. Post-Normal Science for the Post-Normal Age. *Futures*: 739-755

Gibbons, M. 1999. Science's new social contract with society. Nature (402)11-18

Hirsch Hadorn G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy W., Joye, D., Pohl, C., Wiesmann, U. and Zemp, E. (eds), Handbook of transdisciplinary research, Berlin: Springer Verlag, 2008

Ipinge, 2018. Windhoek Transformational Leadership on Climate Change Training for City of Windhoek's Strategic Executives. Training report. Available online at: http://www.fractal.org.za/wp-content/uploads/2019/05/Strategic-Executive-

Transformational-leadership-on-climate-change-Training_City-of-Windhoek_Report_16042019-web.pdf
Jack, C. 2019. Climate risk narratives: envisioning possible futures for your city. Poster produced as part of the FRACTAL project.

Klein, J.T. 2013. The transdisciplinary moment(um). Integral Review 9 (2):189–199

Kumu [Relationship mapping software]. 2019. Retrieved from https://kumu.io

Lindley, D. 2015. Elements of Social Learning Supporting Transformative Change. Southern African Journal of Environmental Education, 31(1), 50-64.

McClure, A & Koelle, B. 2017. FRACTAL learning framework. Internal document produced for the FRACTAL project.

McClure, A. 2017. FRACTAL governance and decision-making processes. Internal document produced for the FRACTAL project.

Ndebele-Murisa MR, Mubaya CP, Pretorius L, Mamombe R, Iipinge K, Nchito W, et al. (2020) City to city learning and knowledge exchange for climate resilience in southern Africa. PLoS ONE 15(1): e0227915.

Nowotny, H., Scott, P., & Gibbons, M. (eds) Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty, Cambridge UK, Polity, 2001

Polk, M. 2014. Achieving the promise of transdisciplinarity: a critical exploration of the relationship between transdisciplinary research and societal problem solving. Sustainability Science, 9(4): 439–451

Polk, M. 2015. Transdisciplinary co-production: Designing and testing a transdisciplinary research framework for societal problem solving. Futures (65): 110–122

Pretorius, L., Taylor, A., Iipinge, K.N., Mwalukanga, B., Mucavele, Mamombe, R., Zenda, S. and McClure, A. 2019. An Embedded Researcher approach to integrate climate information into decision making in southern African cities: lessons from FRACTAL. FRACTAL working paper. Available online at: http://www.fractal.org.za/wp-content/uploads/2019/07/Pretorius-L-et-al-Embedded-Researcher-approach.pdf

Prieur-Richard, A.H., Walsh, B., Craig, M., Melamed, M.L., Colbert, L., Pathak, M., Connors, S., Bai, X., Barau, A., Bulkeley, H., Cleugh, H., Cohen, M., Colenbrander, S., Dodman, D., Dhakal, S., , Dawson, R., Espey, J., Greenwalt, J., Kurian, P., Lee, B., Leonardsen, L., Masson-Delmotte, V., Munshi, D., Okem, A., Delgado Ramos, G.C., Sanchez Rodriguez, R., Roberts, D., Rosenzweig, C., Schultz, S., Seto, K., Solecki, W., van Staden, M. and Ürge-Vorsatz, D. 2018. Extended version: Global Research and Action Agenda on Cities and Climate Change Science. Produced for IPCC. Available online at: https://citiesipcc.org/wp-content/uploads/2018/09/Research-Agenda-Aug-10_Final_Long-version.pdf

Saldana, J. 2013. The Coding Manual for Qualitative Researchers (Second edition). Sage publications.

Scharmer, C.O. 2004. Fieldnotes: illuminating the blind spot of leadership. Fieldnotes: A newsletter of the Shambhala Institute. Sept. 2004, Issue 6.

Scharmer, C.O. 2012. The essentials of Theory U: core principles and applications. Berret-Koehler Publishers, Inc., CA, 2018.

Schauppenlehner-Kloyber, E., & Penker, M. (2015). Managing group processes in transdisciplinary future studies: How to facilitate social learning and capacity building for self-organised action towards sustainable urban development? Futures (65) 57–71.

Scott, D and Taylor, A. 2019. Receptivity and judgement: expanding ways of knowing the climate to strengthen the resilience of cities. FRACTAL working paper. Available online at: http://www.fractal.org.za/wp-content/uploads/2019/02/Scott-D-and-Taylor-A-Receptivity-and-Judgement-web.pdf

Soal, S. 2019. Process reflections out of the annual meeting and before. On facilitation, animation and learning as community building in a transdisciplinary approach. Internal reflections produced for the FRACTAL project.

Taylor, A, in McClure, A. 2019. FRACTAL annual meeting report (2019). Available online at: http://www.fractal.org.za/wp-content/uploads/2019/04/FRACTAL_Annual-meeting-2019_report_15032019.pdf

Taylor, A., Scott, D., Steynor, A and McClure, A. 2017. Transdisciplinarity, co-production and co-exploration: integrating knowledge across science, policy and practice in FRACTAL. FRACTAL working paper. Available online at: http://www.fractal.org.za/wp-content/uploads/2017/03/Co-co-trans_March-2017.pdf

Annex A: Data sources used in the study

Data	Description	Scale	Referencing
Semi-structured interviews (team members and lab participants in Lusaka and Windhoek) n = 20 interviews	These were implemented with individual stakeholders across the project and in Lusaka and Windhoek (at the time of the development of the working paper) with 32 questions, ranging from simple to more complex	Individual: participants of methods in Lusaka and Windhoek as well as team members	e.g. SSI1 (semi-Structured Interview 1)
Reflective surveys on the entire learning lab journey (lab participants) n = 3 reflection sheets with anonymous responses: 26 from Lusaka, 18 from Maputo and 37 from Windhoek	These were collated in person at the end of the last learning lab in Lusaka, Maputo and Windhoek, in the format of individual feedback sheets with four simple questions	Individual: participants of methods in Lusaka, Maputo and Windhoek	e.g. RSLL-L (Reflective Survey Learning Lab Lusaka)
Reflective surveys on the whole project (FRACTAL team) n = 1 sheet with 46 anonymous responses	These data were collected in person at the last annual meeting in the format of individual feedback sheets with four simple questions. Similar to the Reflective Surveys on the entire learning lab journey but in this instance, team members were requested to answer in the context of the project as a whole instead of the processes in their specific city	Individual: all project team members present at the annual meeting in 2019, ranging from researchers to city decision makers	RSFP (Reflective Survey Fractal Project)
Reflections after each lab n = 13 reflection sessions	Face-to-face, facilitated through quick exercises with the participants and/or discussions within the team	City community and research team; participants of methods in Lusaka, Maputo and Windhoek	e.g. LLR-L1 (Learning Lab Reflection - Lusaka 1)
Documented webinar reflections after each learning lab n = 13 webinars	Virtual, after each learning lab, webinars were hosted during which all project partners were invited to listen to an overview of the process, as well as reflect on the outcomes of this process and next steps	FRACTAL team: anyone interested in joining the webinar reflections	e.g. DWL-L11, (Documented Webinar Lusaka - Learning Lab 1).

Data	Description	Scale	Referencing
Documented topical learning webinars and discussions n = 3 webinars	These were hosted virtually to discuss pertinent issues related to FRACTAL, namely: what have the climate science learnings been through TD research in cities, what have we tried and learned with regards to Climate Risk Narratives, and discussing the benefits of city-university partnerships	FRACTAL team (and beyond): anyone interested in joining the topical learning webinar	e.g. DTLW1 (Documented Topical Learning Webinar 1)
Annual learning surveys n = 2 sheets (2017 and 2018) with 20 and 13 anonymous answers respectively	Annual learning surveys were sent out in 2017 and 2018 to provide an opportunity for project partners to provide feedback and suggestions related to FRACTAL. The format was an online survey including 8-12 questions.	Individual: FRACTAL team	ALS1 (Annual Learning Survey 1 2017), ALS2 (Annual Learning Survey 2 2018)