



Linking Local Projects With Global Processes: Learning From Transdisciplinary Collaborations in African Cities

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Specialty section:

This article was submitted to
Innovation and Governance,
a section of the journal
Frontiers in Sustainable Cities

Received: 31 October 2021

Accepted: 21 February 2022

Published: 17 March 2022

Citation:

Patel Z, Schneider F and Paulavets K
(2022) Linking Local Projects With
Global Processes: Learning From
Transdisciplinary Collaborations in
African Cities.
Front. Sustain. Cities 4:806053.
doi: 10.3389/frsc.2022.806053

The central role of science and robust data sets as a means for advancing sustainable development has gained traction across science and policy communities globally. Furthermore, strengthening the science-policy interface in ways that link scientific knowledge production and societal problem solving requires both inter-disciplinary collaborations, as well as collaboration between researchers and extra-scientific actors. The paucity of data and understanding of the distinctive dynamics shaping Africa's urban transition provide an increasing impetus for engaging alternate and inclusive knowledge partnerships. Whilst the number of knowledge collaborations across African cities is increasing steadily, critical engagement with the practice of transdisciplinary approaches and the potential these alternate knowledge configurations might have for steering Africa's urban future(s) is limited. Drawing on the application of transdisciplinary approaches across 11 projects from the Leading Integrated Research for Agenda 2030 in Africa (LIRA 2030 Africa) programme on *Advancing the implementation of SDG 11 in cities in Africa*, this paper provides insights into the role of transdisciplinary approaches in bridging between local projects and global agendas. Evidence from the LIRA programme illustrates a positive relationship between carefully and purposefully constituted project teams who engage deeply with local contexts and the relevance of the resulting interventions. The common but differentiated experiences across the LIRA projects make it clear that the future of African urbanism is not singular but differentiated according to different local contexts. These projects simultaneously address the conceptual and service delivery deficits in local areas, whilst highlighting blind spots in global policy agendas that are misaligned to the complexity of African cities. The significance of transdisciplinary approaches that link the "what" to the "how" of urban change, is found to be critical in data poor post-colonial contexts, which are urgently in need of evidence-based policy reform shaping the reconfiguration of service delivery mechanisms. Finally, the significance of transdisciplinary research by early career scholars in and of Africa serves to shift the political economy of research on Africa, contributing to the transformative potential of urban experimentation in bridging between the global and the local.

Keywords: transdisciplinarity, African cities, urban transitions, learning, SDG 11

INTRODUCTION

The evidence that cities are key to addressing the global environmental challenges of the Anthropocene is firmly established. With over 50% of the globe being urbanized (UN DESA, 2018), cities are major sources of environmental degradation as they are centers of consumption and production (Satterthwaite and Dodman, 2013). Simultaneously, cities are sites of innovation and creativity, with the potential to steer global sustainability transitions. Global and local policy architectures are increasingly reflecting this dual role of cities in addressing sustainability challenges, with Agenda 2030,¹ Agenda 2063 of the African Union,² the Paris Agreement on Climate Change,³ the Sendai Framework on Disaster Risk Reduction⁴ and the New Urban Agenda⁵ all recognizing the central role of cities in transformation toward sustainable development. The success of these global agendas depends in turn on the availability and accessibility of robust data, as well as the reconfiguration of governance systems that can support urban transformation. The assumptions that underpin the success of these global agendas are misaligned to the complexity of African cities (Patel et al., 2017). African cities present unique opportunities given that they display the fastest urbanization rates in the world: whilst the bulk of urbanization is in progress with a forward growth trajectory seeing the continent reaching 60% urbanization in 2050 (UN Habitat, 2020). Furthermore, Africa's "urban revolution" (Pieterse and Parnell, 2014) is set against a backdrop of global imperatives of fostering low-carbon smart cities, with technology-based solutions to mitigate environmental impacts and address resource scarcity (Buyana et al., 2019; Patel et al., 2020; Kovacic et al., 2021). The challenges, however, are that the majority of urban dwellers will continue to live in informal systems, which renders improving access to urban services unsurprisingly difficult (Breda van and Swilling, 2019). Furthermore, weak governance systems and outdated urban colonial planning systems characterize many African contexts (Fox and Goodfellow, 2016; Muchadenyika and Williams, 2016; Matamanda et al., 2021). Based on spatial and demographic shifts alone, the significance of urban change in African cities for global sustainability over the next decades cannot be underestimated. Given the need for robust governance responses and the scale of technological innovation required to address global sustainability goals, African cities must therefore forge alternate transition pathways (Pieterse and Parnell, 2014; Buyana et al., 2019). In this paper, we engage with the premise that policy reform and

innovation that is fit for purpose will require inclusive knowledge partnerships that are able to experiment with niche innovations in imagining and reshaping Africa's urban future(s).

The central role of science and data as a means of advancing sustainable development has gained traction across science and policy communities globally. *Nature Sustainability's* expert panel on Science the Future of Cities (2018) highlight the three-fold role of science for the future of all cities. 1) to understand how cities work; 2) to provide an understanding of the opportunities and challenges cities afford to humanity; and 3) to inform how we can harness these to transition to more sustainable and just societies. Furthermore, strengthening the science-policy interface in ways that link scientific knowledge production and societal problem solving requires both inter-disciplinary collaborations, as well as collaboration between researchers and extra-scientific actors. Getting solutions to scale requires the transformation of current interfaces between science and policy by breaking down the conventional divides between science and politics and by derailing notions of who does science where, and who does politics and where. Transdisciplinary practices have been shown to be an effective vehicle for facilitating the production of knowledge through alternate tracks and forging much needed alternate pathways to urban progress.

The paucity of data and understanding of the distinctive dynamics shaping Africa's urban transitions provide an increasing impetus for engaging alternate and inclusive knowledge partnerships. In this context, transdisciplinary knowledge partnerships across disciplines and beyond academia are gaining increasing traction in order to access and engage alternate knowledges, perspectives and experiences. Given the promise of transdisciplinary approaches as more inclusive and relevant for engaging with complex urban issues, a number of urban experiments are emerging that aim to stimulate new evidence required for practice and policymaking. Knowledge partnerships between academic researchers, local government officials, civil society, and local communities are regarded possible means of bringing together urban stakeholders to explore and design solutions to pressing urban challenges (Polk and Kain, 2015). The history of scholarship on transdisciplinary engagement is well-established in the global north, however, given the distinctiveness of African urban trajectories, it is prudent to revisit assumptions regarding the transformative potential of transdisciplinary practices specifically in African contexts. Given the characteristics of "Africa's urban revolution," we explore the extent to which distinguishing approaches to transdisciplinarity are emerging. There is an emerging evidence base in the literature on knowledge co-production partnerships in African contexts (Brown-Luthango, 2012; Anderson et al., 2013; Breda van and Swilling, 2019); the relationship between knowledge co-production and innovation development for urban change (Patel et al., 2017; Ambole et al., 2019; Buyana et al., 2019; Buyana, 2020); as well as contributions on different models for delivering transdisciplinary research (Patel et al., 2015; Perry et al., 2018; Culwick et al., 2019). Notwithstanding these and other contributions on transdisciplinary approaches in African cities, little is understood about the relationship between locally based knowledge partnerships and their potential to

¹Agenda 2030: Transforming Our World - the UN Plan of Action for Sustainable Development, including 17 Sustainable Development Goals, ratified in September 2015.

²Agenda 2063: The Africa We Want—Africa's strategic framework to deliver on inclusive and sustainable development, 2013–2063.

³The Paris Agreement is a legally binding international treaty on climate change, adopted by 196 parties at COP 21 in Paris in December 2015, entered into force in November 2016.

⁴The Sendai Framework was adopted in Sendai, Japan with the aim to reduce disaster risks over 15 years (2015–2030).

⁵The New Urban Agenda is a shared vision for a more sustainable future, adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador in 2016.

contribute to global policy imperatives. The need for knowledge partnerships gains in significance in the context of the global Sustainable Development Goal 11 (SDG11) that seeks to make cities and human settlements inclusive, safe, resilient, and sustainable. In this paper, we address three questions: First, what is the significance of transdisciplinary approaches for the delivery of relevant urban outcomes? Second, what role do transdisciplinary research projects play in bridging between local projects and global agendas? Third, is there a distinctive approach to transdisciplinarity emerging from Africa?

We respond to these questions based on evidence drawn from a pan-African transdisciplinary research programme, Leading Integrated Research for Agenda 2030 in Africa (LIRA 2030). Between 2018–2020, 11 projects in 17 cities across 12 African countries were supported by the International Science Council to forge collaborative research partnerships focused on the theme *Advancing the implementation of SDG 11 in cities in Africa*. The funding call links the global sustainable development goal (SDG) that recognizes the central role of urbanization in sustainable development with ambitions to deliver new knowledge to support the fostering of safe, resilient, and sustainable cities and human settlements. We address the research questions by engaging with: a) The diversity of practices of transdisciplinarity across the projects; b) understanding the role of diverse local contexts on project design and action; and c) identifying key enablers and challenges for transdisciplinary research; and d) identify the results emerging from collaborative processes. As such, our primary interest is with the “how,” or the process dimensions of transdisciplinary approaches in African cities, rather than the “what” or the specific sustainable development outcomes. Ultimately, this paper seeks to deepen not only the knowledge and learning about African urban challenges but will also add to the compendium of understanding of how we can “learn” about such complex wicked problems through transdisciplinary collaborations. By engaging with and documenting the experiences of local projects implementing global agendas, this paper contributes to emerging literature on the development and potential of collaborative knowledge practices in Africa.

METHODS

The 11 projects analyzed in this paper constitute the second of three cohorts of projects funded through a unique programme that seeks to build capacity for early career scientists in Africa to undertake transdisciplinary research and to foster scientific contributions to the implementation of Agenda 2030 in African cities. The programme, initiated in 2016, is funded by the Swedish International Development Cooperation Agency (SIDA), and delivered through a partnership between the International Science Council and the Network of African Science Academies (NASAC). Over the duration of the programme, three consecutive funding calls resulted in the training of over 100 early career scientists on transdisciplinary research approaches, and funded 28 projects across 3 cohorts, including 22 African countries. The programme is distinctive as

it: a) promotes transdisciplinary research and partnerships; b) fosters collaboration between two African cities in each project; c) links local projects with global scientific policy processes; and d) increases funding and institutional support in Africa. These distinctive features provide an opportunity to learn from transdisciplinary approaches for sustainable urban development in Africa.

The projects in this cohort were successful grantees responding to a funding call focused on *Advancing the Implementation of SDG 11 in cities in Africa* (LIRA, 2017). This funding call links the global sustainable development goal (SDG) that recognizes the central role of urbanization in sustainable development with ambitions to deliver new knowledge for to support the fostering of safe, resilient, and sustainable cities and human settlements. The other LIRA cohorts (not the basis of paper) include a focus on Understanding the “energy-health” and “health-natural disasters” nexuses in African cities (LIRA, 2016); and *Pathways toward Sustainable Urban Development in Africa* (LIRA, 2018). The geographical reach of the projects in cohort 2 includes 17 cities from 12 countries (**Figure 1**):

The partner cities are as follows:

- Lagos, Nigeria and Accra, Ghana
- Kampala, Uganda and Nairobi, Kenya
- Dar es Salaam, Tanzania and Durban, South Africa
- Ouagadougou, Burkino Faso and Tamale, Ghana
- Windhoek and Gobabis, Namibia and Lusaka, Zambia
- Kisumu, Kenya and Kumasi, Ghana
- Durban, South Africa and Luanda, Angola
- Stellenbosch, South Africa and Accra, Ghana
- Luanda, Angola and Maputo, Mozambique
- Durban, South Africa and Harare, Zimbabwe
- Cape Town, South Africa and Douala, Cameroon

The projects in this cohort include:

- P1:2: Standardizing City-level data gathering toward achieving Sustainable Development Goal 11 in Africa (SCiLeD) (Lagos and Accra).
- P2:2: Co-creating an Urban Framework for Localized Norms on Sustainable Energy (Kampala and Nairobi).
- P3:2: Integrating sustainable water and sanitation solutions to create safer, more inclusive and climate resilient cities in Tanzania and South Africa (Dar es Salaam and Durban).
- P4:2: Green Spaces and Repurposing Waste: Building Capacities for Resilience in Urban and Peri-urban West Africa (Ouagadougou and Tamale).
- P5:2: Community-led upgrading of informal settlements (Windhoek, Gobabis, and Lusaka).
- P6:2: Management of shared sanitation facilities in low-income settlements (Kisumu and Kumasi).
- P7:2: Realizing the potential of urban density to create more prosperous and liveable informal settlements in Africa (Durban and Luanda).
- P8:2: Bridging decentralized energy planning with neighborhood-level innovations in cities of Africa: Case studies from Ghana and South Africa (Stellenbosch and Accra).



FIGURE 1 | Cohort 2—Geographical reach.

- P9:2: Co-producing urban knowledge in Angola and Mozambique through community-led data collection: toward meeting SDG 11 (Luanda and Maputo).
- P10:2: Transforming Southern cities in a changing climate (Harare and Durban).
- P11:2: Integration of housing and health policies for inclusive, sustainable African cities (Cape Town and Douala).

This desktop study analyses a range of internal programme reports and documents prepared by project Principal Investigators in collaboration with their research partners including: Project proposal (2017), 2 annual reports (2018 and 2019), and two self-reflection workshop reports (2018 and 2019) and a Final Project Report (2020). The project proposals are used as a baseline of what was intended with respect to project design

and assumptions. The annual reports reflect on achieved results, enablers, and challenges, and highlight changes in research design and learning. In order to build in a reflexive practice within the projects, self-reflection guidelines were designed by the authors of this paper for PIs to use with their research teams twice during the research process. The self-reflection report template provided opportunities for reflexive practice, allowing the projects to continuously adapt their assumptions and to (re)tailor their pathways to change, thereby improving the effectiveness of projects' interventions.

The analysis of the data was guided by the development of a conceptual framework based on reviews of the literature is presented in the next section (Schneider et al., 2018). Several sub-themes were identified for each of the study goals, which in turn contributed toward the development of an analytical framework to assess the individual projects. Data from the reports detailed above were extracted as appropriate to populate the analytic grid. Analysis across the 11 projects was then conducted to identify high level trends and patterns, as presented in the findings.

CONCEPTUAL APPROACH

Transdisciplinary research is premised on the assumption that multiple knowledges will result in more useful research and practice outputs. A number of assumptions underlie calls for inclusive knowledge partnerships, including the benefits, challenges, and processes through which transdisciplinarity provides alternate and enriching approaches to complex urban sustainable development challenges. While mindful of the breadth of transdisciplinarity ranging from metaphysical and mystical perspectives (Nicolescu, 2012) to research aimed at designing solutions to “real world problems” (Gibbons and Nowotny, 2001), for the purposes of this paper, transdisciplinary research is interpreted as focused on societal problem-solving, through in-depth interactions between academic researchers across disciplines and various societal actors, including academic researchers, local government officials, civil society, and local communities. In urban contexts, these partnerships are a steppe change away from the state responding to citizen service delivery needs, to collective engagement between distinct stakeholder groups to enhance and move forward ideas and methods on service delivery (Patel et al., 2020). These engagements create new outcomes that each group may have been unable to achieve on their own. The value of these interactions therefore lies in the bringing together of diverse knowledge types with the purpose of stimulating sustainable change. However, new knowledge can only be taken up if the institutional setting and culture is able to respond to and act on this knowledge to give it effect.

Diversity of Transdisciplinary Practices

We recognize that there is no single “right way” of doing transdisciplinary research, and that the African context might result in practices that have not been extensively documented in the literature. In capturing and learning from the diversity of transdisciplinary practices across LIRA projects, we focus on the diversity of collaborative processes deployed to support transformation for the benefit of society. What these processes

have in common is the integration of experiences, expertise, and knowledge from different urban actors to co-create solutions to societal problems (Polk and Kain, 2015).

The review of collaborative processes includes tracing the range of ways in which different knowledge actors engage over project lifespans. Here, factors that are pertinent to partnerships were considered including: the different stages from project initiation, such as including how partnerships were identified, initiated, and developed. The roles of partners in project set up, including governance arrangements and specific intermediary roles, bridging between science and policy, were examined. Process factors influencing knowledge creation and learning occurred between different actors engaging across disciplines and institutions; the spaces for engagement, or the geography of engagement; and the approaches used to integrate different knowledge types to inform urban change.

Learning From Diverse Approaches to Change

All LIRA projects aim to generate action-oriented knowledge, or knowledge that can be actioned. Knowledge generated through partnerships must therefore have relevance at the science policy and society levels. As such, action could be about scaling experimental technological innovations inherent in urban transitions, or using urban knowledge to inform decisions to improve the daily lives of citizens. To be effective in these different action spaces, projects themselves need to be reflexive and responsive, and have the ability to change their own actions and choices in the process of knowledge co-production. We focus therefore on the assumptions held by projects regarding actions required for transformative change and tracked changes in actions at the project level based on learning as the projects unfolded. We documented the diversity of approaches amongst the projects, as well as the driving forces informing action at the project level. Transdisciplinary research is by its nature emergent and iterative, it was expected that as project teams acquire new knowledge about the problem, develop new networks, learn more about underlying causes, and respond to contextual factors, that they will make adjustments to projects in the process of implementation. Whilst it was assumed that each project has a unique approach to change, because they work in different contexts toward different goals, the following elements, based on the literature (Vogel, 2012; Green, 2016; Thornton et al., 2017), were included in the analysis: The rationale informing the transformation vision or problem being addressed; the knowledge gaps and assumptions about how societal change can be effected; the context knowledge based on the conditions for change including worldviews, power relationships, institutions, skills, amongst others; the transformation pathways and strategies used to accomplish outcomes; and the monitoring and evaluation procedures used to learn about the impact of activities.

Enablers and Challenges for Change

Pathways between new knowledge derived through transdisciplinary processes and sustainable urban transitions are

not solely dependent on knowledge. New knowledge can only be taken up if the institutional setting and culture is able to respond to and act on this knowledge to give it effect. As such, we sought to highlight structural changes within and between institutions. Factors influencing structural change amongst diverse research partners has been shown in the literature to be dependent on a number of factors including time demands and limitations, the role of the individual in co-production processes, institutional mismatches (including the different conditions under which individuals and organizations can participate in collaborative processes), and communication barriers between diverse actors (Polk, 2015). Less well-documented and understood are the factors influencing urban change in African cities. African cities display a number of unique characteristics which may or may not have a role to play in shaping knowledge co-production practices; but nonetheless have a role to play in shaping the outcomes and hence effectiveness of co-production efforts (Greyling et al., 2017). These features include weak governance systems, inadequate capacity, high levels of inequality, corruption, increasing levels of informality (presenting a data challenge), informal governance systems, amongst others (Parnell and Pieterse, 2014). We investigate the extent to which some of these factors, including but not limited to knowledge, act as enablers and/or challenges for knowledge co-production in the African context.

Capturing Impacts

Building on studies on societal impact (Godin and Dore, 2005; Bornmann, 2013; Miettinen et al., 2015), we explore the links between transdisciplinary research and sustainability impacts. These frameworks usually consist of a series of stages, such as inputs, research processes, direct outputs, and further outcomes, which are connected over various feedback loops. Recently, sustainability researchers have also begun to apply such frameworks, operationalizing them with more specific categories or indicators (Wiek et al., 2014; Mitchell et al., 2015; Kaufmann-Hayoz et al., 2016). For the purposes of this article, impact indicators include knowledge products of relevance to both research and society ranging from publications to design interventions; enhanced capacities and learning; the expansion and strengthening of networks; and structural changes and decisions resulting from TD collaborations.

FINDINGS

Transdisciplinary Practices

In bringing multiple knowledges to bear to address societal problems, the focus here is on the mechanisms through which interactions between diverse urban actors were initiated. In the main, the Principal Investigators (PIs) developed their project proposals based on established research projects (P9:2, P10:2) and or partnerships (P3:2, P7:2, P8:2, P11:2). Researchers indicated that building on existing projects and networks proved an effective means to initiate proposal development. In projects where teams at the proposal stage constituted new partnerships, PIs emphasized the importance of early and sustained engagement to build a rapport and common purpose

(P1:2) once the project was initiated. In all cases however, PIs stressed the importance of investing time in building relationships between research partners at the project initiation stage in order to identify additional relevant partners, and to allow the research teams to efficiently determine the key research priorities between partners (P3:2; P9:2; P10:2). All PIs emphasized the significance of building trust between partners as an attribute that needs deliberate attention and investment to foster productive partnerships.

Despite the varying modes for identifying project partners within cities and between the two project cities, in general, all projects identified the significance of conducting desktop reviews (of the literature and existing policy frameworks) as well as site/field visits to focus the research questions and ensure they are of relevance to all stakeholders. In some cases, a desktop study was conducted in the pre-proposal stage (P4:2), whilst in other cases the identification of research gaps emerged from previous or ongoing studies, which also offered opportunities for field visits prior to the development of the proposal. Irrespective of the history of projects, once awarded, all projects conducted in-depth project specific desktop studies and field visits. Stakeholder mapping exercises and/or multisectoral workshops were also carried out as a means of triangulating and diversifying project partners. Intermediaries were identified as entry points into community groups. For example, in P2:2, the University of Nairobi worked with Mwamko Children's Center to gain access to community groups.

All projects share the scientific goal of generating empirical data on urban processes and dynamics in informal and peri-urban contexts. This objective to generate empirical data is a recognized constraint facing decision makers in Africa, where data and understandings of urban processes in informal contexts is extremely thin. Generating empirical data on a wide range of issues was secured through the convening of diverse project teams including scientists and experts with disciplinary specializations in both the natural and social sciences, including epidemiologists, engineers, hydrology modelers, urban planners, urban sociologists, urban geographers, humanitarian engineers, anthropologists, architects. The innovation in some of the projects is in the process of generating data itself, as a direct response to the goals and targets included in the SDGs (e.g., P1:2 and P9:2 which both utilized community groups to collect data relevant to SDG 11). Whereas, in other projects, focus on generating data to better understand the scale of the urban challenge in specific sectors to respond appropriately is the focus. Projects focussed on innovation in service delivery through local level experimentation include a sectoral focus [e.g., Energy (P2:2 and P8:2); Water and Sanitation (P3:2 and P6:2); Waste Management (P4:2); Housing (P5:2, P7:2 and P11:2); Health (P:11:2)]. P10:2 and P:3 is both linked to climate change. Although the primary focus of projects is largely on sectors, on closer inspection of the projects, questions around governance, skills, and capacity development are regarded as critical pathways to transformation.

As the goals of projects in this cohort were aimed at innovating around systems and methods to generate data and/or provide solutions to challenges faced by informality in African

cities, the focus has largely been on documenting community perceptions and engaging community partners in shaping the provision of alternate infrastructure delivery options including sustainable energy technologies (P2:2 and P8:2), water and sanitation solutions (P3:2), or in data collection for example P1:2 and P9:2. Much focus has also been placed on understanding the policy context for delivery (e.g., P10:2, with its focus on climate adaptation, P2:2, focused on urban frameworks, and P11:2, integrating health and housing policy interventions). Outcomes addressing societal goals were shown to be dependent on appropriate forms of dissemination of results, such as through processes of community engagement (P1:2). Social media platforms were identified as tools for disseminating key messages to large groups. Projects identified increased awareness amongst local community and policy making partners of the nature, scale, and possibilities for addressing urban challenges as significant societal outcomes. For example, P3:2 and P6:2 have demonstrated the benefits of alternate approaches to sanitation on site, providing tangible benefits to communities and compelling evidence of alternatives for policy uptake. Similarly, P7:2 and P5:2 developed alternate housing delivery prototypes that simultaneously meet scientific and societal goals.

Whilst the project reports described a range of transdisciplinary modes of engagement, “participatory” is a descriptor that featured across the majority of projects. There are very clear efforts to engage communities and/or policy communities (as per project goals) as research partners. Project partners are trained and engaged in data collection (P1:2 and P9:2); and in co-creating solutions and management approaches to service and infrastructure delivery. Multistakeholder workshops engaging stakeholders beyond the project team (P7:2), internal project team co-design workshops (P3:2), landscape analysis workshops (P4:2), social embeddedness (P8:2), themed workshops, such as Urban Dream (P5:2), community studios (P5:2); learning labs (P10:2), focus groups, and field visits—are amongst the methods used to bring different knowledge systems together. One PI identified community meetings and focus groups as being most effective for his specific project needs as “this provided a chance for participants to actively interact with the research team, argue, question, and give individual opinions related to the study” (P3:2). An important observation made by some PIs is the need to use different formats for different stakeholder groups and for different purposes. Across the projects, multiple formats of engagement were used over the lifespan of the projects.

Many of the projects were set up in phases, starting with co-design, then co-producing activities, and lastly communication and dissemination. Most PIs indicated that stakeholder engagement was very useful in project co-design and framing of the research questions. However, the extent to which engagement was considered useful across other phases of the project (including data collection, development of knowledge products, dissemination of knowledge products, implementation of outcomes) varied depending on the goals of the project. For example, P1:2 and P9:2 were both designed to engage communities in data collection; as such, these PIs specifically

noted the value of including communities in data collection. By contrast, projects focused on governance and policy change highlighted the value of dissemination of knowledge products including policy briefs as a mechanism to reach policy communities. Therefore, the extent to which engagement is valued at different steps in the research process is not uniform across projects and are shown to be dependent on the project goals and intentions.

Projects used boundary objects to work at the boundaries of knowledge and expertise. In a number of cases, the innovation and/or technology being introduced (e.g., briquettes, house design, sanitation technology) became the object that was used to bridge between different knowledge domains. In other instances, photography and other artistic representations were found to be useful boundary objects that were used to mediate cross-disciplinary learning. In P2:2, the convergence of different research traditions and methodologies enabled the project to come up with a hybrid approach known as Transdisciplinary Visual Ethnography (TVE), which relies on co-producing visual depictions in different media, including photography, technical drawings, symbols, maps—with storylines from local community actors. This more democratic means of producing knowledge shifts the power dynamics in knowledge production, where engagement is not confined to access to expert disciplinary based knowledge, driven by researchers. Similarly, P2:2 made use of the principles of visual ethnography, which entails a situational combination of field techniques for exploring how learning about social phenomena occurs. The visual representation of how communities give meaning to the SDGs resulted in the development of a Local Agenda 2030 for Kampala City, which captures shared interpretations of the goals and targets.

PIs emphasize the significance of face-to-face engagement, and the vital role of processes aimed at building trust. There are also reflections on the significance of space, and where, when, and how engagement happens. One PI notes “the creation of space is necessary for alternatives to emerge” (P8:2); whilst another records “we changed the venue for the policy dialogues to lunch time to be more inclusive” (P2:2). The significance of dialogue, physical meetings and connections between partners in order to integrate different knowledge types was highlighted by almost all PIs in cohort 2.

Acquired Learning and Actions

All LIRA projects aim to generate action-oriented knowledge that would contribute to addressing policy and society specific urban challenges in two different African cities. In the proposals, each project outlined a strategy and set of actions that the research team believed would help them to achieve the projects’ goals. The findings in this section draw on the two self-reflection reports compiled by the PIs, which reflect on the extent to which projects were able to continuously adapt their assumptions and the extent to which they were able to (re)tailor their pathways to change in order to improve the effectiveness of projects’ interventions.

All projects have a unique approach to change because they work in different contexts with different goals. Whilst approaches

to change were captured in project proposals, PIs developed explicit theories of change at a coaching workshop offered by the LIRA programme in Port Elizabeth, 2018 to capture the assumptions underlying their projects. Numerous changes in project activities were noted by the PIs. Changes to project activities were described as “learning opportunities.” Two drivers for learning and change were identified: a) internal factors, including reflection and monitoring and evaluation processes, built into project design; and b) external factors that emerge from the research context. Firstly, PIs cited individual internal monitoring and evaluation processes as well as the self-reflection workshops as opportunities and triggers for change. The co-design phase was identified as a critical juncture for learning between partners, which resulted in project design changes. For example, P7:2 changed one of the cities as a result of stakeholder and desk-top engagement in the early stages of the project, when new opportunities and research challenges were presented.

The kinds of actions or changes that were made to projects include:

- Adaptation of the research instrument to meet contextual needs (including local knowledge and languages) in P1:2;
- Changes in venues and timing for policy dialogues to be more inclusive in P2:2;
- Changes in emphasis, identified key areas to put more effort to successfully attain goals in P3:2 and P10:2;
- Changes in stakeholders. For example, in P4:2, the Landscape Analysis resulted in the inclusion of septic tank emptiers, cleaners of open storm sewers, and sludge truck drivers; whilst dairy farmers were not seen as key stakeholders and were then excluded;
- Changes in project partners (P10:2) in order to diversify the disciplinary spread to better fit the goals of the project;
- Changes in geographical scope, including additional sites (P10:2 and P8:2); to changing sites from Cape Town to Durban in P7:2;
- P8:2 saw a change in PI, drawing from the existing project team for continuity.

In some cases, the triggers resulting in change created significant learning moments within the projects. These included:

- In P2:2, the project team used the term “informal” in the framing of the research questions. The team received unfavorable feedback from communities, as describing local energy enterprises as “informal” raised questions amongst authorities regarding taxes, licensing, regulations etc. As a consequence, three intensive dialogues with policy makers and communities were held. P6:2 had a similar experience with the use of the term “informal” which resulted in the renaming of the project to reference “low income” rather than “informal.”
- In order to increase focus and intensity of local activities, a planned regional policy forum was replaced by individual forums in each of the two cities in P9:2.
- Collective workshops in Mozambique (P9:2) were hampered by recurrent elections (2018, local and 2019, national). Instead, stakeholders were involved on a more individual basis until data collection was complete.

In some projects, such as P8:2, monitoring and evaluation were built into project design, through reflective learning journals, quarterly assessment reports and monthly meetings. However, in the main, the self-reflection workshops were identified as important opportunities for PIs and project teams to reflect and recalibrate their research processes. PIs identified the value of these workshops as follows: “[the self-reflection workshops] helped us take stock of where we are and where we want to go” (P2:2); “they provided a distance[d] view of the project progress, and forced the team to understand and construct an image of the entire project and possible trajectory it will take” (P3:2); “[the self-reflection workshops] were really useful to see what was working and where new tools were needed to be developed and/or introduced” (P5:2). The workshops have “enriched our appreciation of the process and the impacts on both the scientific and non-scientific partners, which should be encouraged” (P1:2). It was also noted that the workshops were not planned upfront, which presented a logistical challenge. In some cases, these workshops were conducted remotely. In two instances, the self-reflection reports were co-produced by the team (P5:2 and P10:2), which showed innovation and a commitment to learning.

Enablers and Challenges

The ability of projects to progress was found to be influenced by a number of enabling and constraining factors that are not specific to the nature of transdisciplinary knowledge collaborations but were rather contextually defined. Enabling factors were identified as communication, resources and windows of opportunity. Whilst challenges included insufficient time and resources; institutional barriers; inter-city differences; and sustaining partnerships.

The quality, frequency and medium of communication within project teams was highlighted as a significant factor influencing coherence within teams. Shared understanding of the project between the PI and co-PI was secured through “frequent communication” (P1:2) and the “free flow of information between the cities and partners” (P4:2). Whilst some PIs identified the opportunities offered by social media for ongoing communication (P1:2); others reported that WhatsApp and other online platforms were not as effective as face-to-face engagements (P4:2). P1:2 also highlighted the increased effectiveness of more frequent, but smaller meetings. Frequent and in-depth engagements with the project team (P10:2) and with project stakeholders were seen as critical for building trust and buy-in to the research process (P1:2). The significance of building relationships and having a good sense of context through site visits was emphasized as a key enabling factor (P1:2). Working effectively as a team was shown to be dependent on determining communication pathways that sustained continuity and a sense of belonging and joint engagement.

As resources over 2-year projects was limited, PIs had to leverage resources to enable the success of their projects. PIs were successful at leveraging in-kind contributions from host institutions in the form of venues for meetings, office space, administrative support, infrastructure including laboratories. It appears that track record with previous projects and other

ongoing projects gave the PIs credibility within their institutions. Resources were also augmented through streamlining with other research projects and partnering with researchers who were already doing similar work to create synergies (P1:2, P9:2, P10:2). The role of PIs was extended to include entrepreneurial skills to augment, enhance and leverage projects.

Unanticipated windows of opportunity were identified as pivotal moments for projects to amplify and elevate their efforts. For example, in P1:2, one of the project partners received an award in a process being run by the C40 and ICLEI Cities Climate Leadership Group—Local Governments for Sustainability. This recognition bolstered efforts of the project through association. In other instances, policy windows provided opportunities to diversify project partners and influence. The confidence gained by empowered communities in P2:2 provided the necessary engagements to lobby policy processes (P2:2). Similarly, the pathways to impact were shown to be bolstered in studies where there were policy windows that facilitated the uptake and amplification of the work being done at the project level. For example, the credibility built up by research teams in P7:2, P9:2, P10:2 have all resulted in deeper policy engagement as the timing of the projects coincided with opportunities for policy interventions such as inputs into the Voluntary National Review (VNR) on the SDGs in Mozambique (P9:2); and feeding research findings into a review of the informal settlement upgrading policy of eThekweni Municipality (P7:2). And finally, engaging the right stakeholders, through training of staff from local authorities, allowed for easier transitions to implementation in bridging the science-policy divide (P6:2).

Time and resources were cited as the main challenges faced by the projects. Transdisciplinary research requires time for building relationships and resources for processes that don't always yield tangible outputs (P2:2). Two years was considered too short to bring project results to fruition. PIs all indicated that the programme should be extended to a second phase to allow for the consolidation of research findings, deepen engagement, and "enhance societal outcomes if the lifecycle of projects could be increased" (P1:2). A further time related issue raised was that of timing and seasonality. PIs working in informal settlements indicated that research slowed down during the winter months when conditions in informal settlements are particularly harsh (P8:2). During these periods, the risk of social unrest is high, and expectations from community partners for resources and rewards become heightened.

There were numerous delays to project progress that were attributed to host institutions, specifically cumbersome financial systems of universities. PIs highlighted institutional challenges with managing the funding. Difficulties of transferring funds between universities and protracted contracting procedures were raised (P1:2; P8:2). Furthermore, P5:2 had the additional challenge of meeting the National Legal Requirements for cross border research collaborations. A related structural constraint raised by P7:2 was obtaining ethics approval for a project that is iterative and emergent. The PI was unable to provide the level of detail and certainty in method required by the ethics procedures of his institution. To address this, separate ethics applications were made for different parts of the research project,

adding to the administrative burden of the researcher PI. Project management and accountability in transdisciplinary research is clearly challenging in university systems that are not set up for working across disciplines, beyond the university, and between different countries (P7:2).

The differences between the project cities were highlighted as both a learning opportunity, and a significant challenge. Elections in one of the two partner countries (or even in both over the duration of the project) posed delays and challenges for synchronizing activities between the cities (P1:2 and P9:2). Differences in digital connectivity between cities was cited as a challenge (P7:2 and P10:2). Synchronizing activities between two cities was challenging, as projects experienced context-specific delays in coordinating meetings, reporting, and data gathering (P1:2) as a result of time zone and/or hemispheric and seasonal differences. Furthermore, the different cities were often found to be at different stages of policy development and had different windows of opportunity in which researchers could respond (P7:2). Varying local contexts required different research instruments in the different cities (P1:2). The challenge of language is pronounced as there is a spread across anglophone, francophone, and lusophone cities (P1:2, P4:2, P3:2). Even where the two cities both had Portuguese as a common language, elderly stakeholders showed a preference for local languages (P9:2). A further language challenge was the difficulty of translating transdisciplinary and sustainability concepts across the different languages whilst maintaining meaning (P2:2).

Sustaining partnerships over the 2-year period was challenging. PIs identified the fluidity of partners' participation as a constraint, as partners in the civil service changed positions, and community members became increasingly fatigued by the process. Other partnering challenges identified include differing agendas and expectations (P1:2; P8:2); competing conceptions and understandings of the project goals (P2:2); competing partner commitments (P3:2); keeping partners engaged throughout the process (P3:2; P4:3; P5:2; P6:2; P7:2). Different strategies were employed to secure partner participation, including providing incentives for e.g., transport costs were paid for participants to secure engagement (P7:2). Finally, the fragility of relationships was highlighted in the reports—it is extremely easy to lose legitimacy and credibility if something goes wrong in the partnership. PIs have had to work hard to maintain relationships (P3:2; P9:2) through consistent engagement amongst the research team as well as participatory processes to keep stakeholders engaged.

RESULTS AND IMPACT

The effectiveness of transdisciplinary approaches in helping to address complex, wicked challenges in African urban contexts was assessed by identifying the range of knowledge products produced; evidence of enhanced capacities; opportunities for developing network; and institutional structural changes and decision-making emerging from collaborative engagements.

Unsurprisingly, the projects have generated new knowledge and data on urban functioning and dysfunction. However, what

differentiates the data from a traditional research project is that the data produced is not simply of academic interest, but has been produced in partnership with communities and policy makers, ensuring relevance for multiple knowledge communities. Given the range of knowledge partners, it follows that the knowledge products resulting from projects is similarly diverse, tailored to different audiences. Traditional academic outputs, including publications and conference presentations were noted. A number of PIs published on average 2–3 publications over the period of the grant, with plans for further publications; whilst others expressed difficulties in finding the time to publish whilst meeting project and institutional requirements. In these cases, publication plans are in place, with commitment to deliver in due course. All PIs have participated at international and local conferences and workshops. At a policy level, policy briefs and technical reports were cited as knowledge products by P2:2, P5:2, and P9:2. The diversity of knowledge products aimed at the societal level include project websites (P3:2), blogs (P2:2 and P10:2), GIS maps (P4), visual and verbal narratives of communities (P5:2), exhibitions, and a learning brief highlighting learning from the project (P5:2). The use of visual communication has been used effectively used by cohort 2, with a documentary produced by P10:2 being selected to be screened at the Better Cities Film Festival (2020). These products are aimed at making the research and its findings more accessible to a wider audience.

In addition to the new knowledge and data, PIs also note the significance of new methods for data gathering, and for dissemination and communication (P1:2). Other less tangible knowledge products include methodological and technological innovations. Diverse new methods were engaged to enhance stakeholder engagement that are reflexive including Learning Labs (P10:2) to methods for knowledge generation including Transdisciplinary Visual Ethnography (P2:2), which combines ethnography, systematic observation, and interaction with groups in their own environment, using spatial techniques for mapping neighborhood activities and urban sociology (P2:2). Other innovations include technological innovations, including sanitation technology solutions (P3:2), improved energy technologies coupled with changes in energy use practices (P2:2), to the development of preliminary double-story incremental housing designs (P7:2). In addition to the introduction of these new interventions, some findings could be considered innovative, as they shift preconceived assumptions. For example, in Uganda, the research has yielded new insights into defining and assessing adequate housing. Here, community engagement has resulted in new policy criteria for measuring decent housing in contexts of informality. Factors identified as priorities by community groups, including the number and price of iron sheets and tenure status are now recognized as measures of adequate housing. Knowledge uptake was cited by PIs in both, the policy and the community realms. PIs cited evidence of empowered decision makers, who now have evidence-based arguments with which to shape decisions. The “development of a community voice” was cited as an important outcome (P5:2).

Capacity development, which was one of the aims of the LIRA programme, was highlighted as a significant outcome of the programme. Whilst some PIs indicated that they had

prior experience with transdisciplinary research, all PIs indicated that the training offered by the LIRA programme and the ongoing support has enhanced their transdisciplinary capabilities significantly. As the LIRA PIs are early career scholars, many expressed the value of the programme for their development as researchers for example, one PI expressed “...it allowed me to develop into a scholar... realizing that a PhD is only the very first step of many to follow” (P5:2). A tangible measure of enhanced capacity can be gleaned from the publications in peer-reviewed journals and book collections. Conferences and workshops opened new research opportunities for PIs providing platforms to test and disseminate new ideas and research findings. Several PIs cited “deeper conceptual engagement” with various concepts including “transformation” as part of the enhanced capacities derived from the projects. The opportunity for individual growth is therefore of significance. One PI reported “as an early career scholar and a PI, I’ve had to be curious and brave. The programme has helped build my confidence and leadership skills” (P10:2). One of the PIs provided the evidence to show the dominance of scholarship from the global North on Africa and highlights the significance of LIRA in shifting the dominant centers of knowledge production on Africa (P2:2). Postgraduate training was included in P2:2 and P9:2, with P9:2 reporting that the value of training postgraduate students included hard and soft skills. Hard skills included field experience and the use of new research tools and innovative new methods (including photomapping, which have now replaced conventional surveys, P2:2); whilst the soft skills acquired are captured as follows: “the research challenged students’ preconceptions about the poor and the knowledge they hold.” The emphasis in cohort 2 was around enhanced capacity, e.g., described as follows: “the project has contributed to research capacity and local ownership of the research” (P2:2). Whilst the capacities development of the PIs emerged as significant, the projects themselves built capacity amongst policy makers and community groups through workshops and training sessions specific to individual projects.

“Network effects” was a dominant theme reported on by PIs. The opportunities built into the programme to participate in international conferences and workshops were cited as important networking and dissemination opportunities. Furthermore, the training sessions and annual research fora built into the LIRA programme undoubtedly resulted in the strengthening of existing networks whilst facilitating the establishment of new networks, e.g., one PI stated that “our partnership portfolio has expanded” (P2:2). Specific partnerships highlighted include the value of the cross-country knowledge translation and learning across the two partner cities, and between PIs and co-PIs. Conferences and the LIRA training opportunities were cited as opportunities for increasing regional and international networks. During 2019, the LIRA programme provided further funding opportunities for cross-cohort collaboration around publications. Close writing partnerships were built across cohort groups and across projects, diversifying and deepening networks.

New processes and structures are captured on a spectrum from increasing interest and awareness of alternate approaches to uptake of knowledge by stakeholders, and mindset shifts among policy actors. In Lagos for example, structural changes

in operations at the State Urban Renewal Agency were catalyzed by the project and have facilitated synergies and collaborations across agencies (P1:2). In Mozambique, the project has been instrumental in facilitating the preparation of the SDG Voluntary National Reporting and contributing to a collective Voluntary Local Review for municipalities (P9:2). In Durban (eThekweni), transformative adaptation has been added as an agenda item to meetings of the Environmental Health Services at the municipal level because of their engagement in the Learning Labs; whilst in Harare, a climate change desk has been established under the Town Clerk (P10:2). In Angola, the team has been invited by the government to support the development of the National Housing Policy; whilst in South Africa the results are being fed into a review of the informal settlement upgrading policy of eThekweni and the team has been included in the South African COVID-19 informal settlement policy and technical platform (P7:2). PIs attribute these successes to the use of transdisciplinary approaches. One PI indicates that multidisciplinary and non-academic stakeholders have allowed for holistic responses to the re-purposing of waste (P4:2); whilst others have highlighted the importance of contributions from a range of stakeholders to highlighting different approaches and responses (P3:2).

LEARNING FROM TRANSDISCIPLINARY COLLABORATIONS

In this paper, we sought to understand the role of transdisciplinary approaches in bridging between the local and the global; and the significance of transdisciplinary collaborations in shaping alternate transitions pathways in African cities. Tracking 11 transdisciplinary projects across 17 cities in 12 African countries over 3 years provides rich insights into the “how” of collaborating at the local level whilst linking to global goals by *Advancing the implementation of SDG 11 in cities in Africa*.

Building transdisciplinary partnerships were shown to have benefitted from prior relationships and working arrangements. Notwithstanding history, investing time in establishing key research priorities in the early stages of local projects was considered a necessary investment in the long-term success of project partnerships. The choice of scientific experts, policy makers, and community partners were determined by the scientific and societal goals of individual projects. Whilst collaboration around identifying dual project goals required engagement between partners, desktop reviews and site visits were identified as significant to ensure contextual relevance. Levels of engagement and participation between partners were shown to vary across the different phases of projects, with co-design identified as the most critical stage for ensuring inclusivity. Despite the benefits of partnering, not all partners contributed to or benefitted in the same way. Whilst some authors claim that knowledge co-production can result in the “flattening of power relations” in urban research between researchers and other urban knowledge brokers, it is also acknowledged that there is a politics to knowledge co-production and that power dynamics are more likely to be flattened over the period of a project rather than in any one instant during the project cycle.

The transdisciplinary approach was valued for improved knowledge sharing across stakeholder groups and resultant improved skills and capacity, learning between cities, and enhanced institutional collaborations and network building. The increased capacity for learning and adaptation which are key components in action-oriented projects that are responding to local contexts. The iterative and non-binding method underpinning transdisciplinary approaches proved appropriate in African cities, where a number of external factors including political changes and fluidity in stakeholder identities have a strong bearing on project design and implementation. By building monitoring and evaluation and self-reflection exercises into the project design, project teams were able to respond to changing contextual issues. Project agility does however hold risks of disengaging from the objectives of the research. This threat was mitigated by the direction, purpose, and intention laid out for projects through the articulation of their theories of change.

Whilst accessing knowledge across disciplines and forms of expertise were shown to be foundational for spearheading innovative responses to urban challenges, a range of non-knowledge related factors impacted on the direction and actions taken within projects. Communication amongst project team members strengthen the cohesiveness and effectiveness of project teams. The credibility of PIs and their ability to leverage change is shown to increase with external validation through awards and other recognitions. Furthermore, the ability of projects to identify and take advantage of policy windows of opportunity catapulted the impact of projects. Astute PIs that are nimble, observant, responsive, and courageous in responding to changes in context are shown to be essential leadership competencies. The challenges faced by projects ranged from factors including time and resources for conducting impactful transdisciplinary research, to differences between the two project cities, challenges around language (local and scientific), barriers working across disciplines, and competing agendas between research partners. The research flexibility offered by transdisciplinary research and its emphasis on the local context were seen as vital for fostering greater receptiveness from stakeholders, thereby improving the quality of the research and its chances for impact.

Understanding and assessing the impact of transdisciplinary projects is complex and contested terrain. Tangible outputs are not the only indicator of effectiveness, whilst there are often time lags before changes in mindsets and structures are evident. Furthermore, the question of attribution is difficult to discern as multiple factors converge in the process of fostering change. Nonetheless, the clear articulation and differentiation between scientific and societal goals across the projects have translated into a range of knowledge products. Whilst academic publications and conference presentations were the norm, the real innovation in knowledge products lies in the range of interventions tailored specifically for policy and community partners. In particular, the significance of visual articulations of results in particular were shown to have a positive influence on buy-in and uptake. Knowledge generation and sharing of locally grounded knowledge between different actors and stakeholders is undoubtedly a key benefit of transdisciplinary research. Ensuring knowledge resonance across partners was shown to increase

the relevance of the projects resulting in structural changes to real world decisions and policy directions. Nonetheless, the transformative potential of transdisciplinary processes as a means of changing ways of thinking and working translated into structural changes within institutions was unevenly spread across projects. What is clear is that despite the many benefits of transdisciplinary engagements, alternate knowledge practices are a necessary but not sufficient driver of change.

TRANSDISCIPLINARITY AND THE FUTURE OF URBANISM IN AFRICA

In responding to global agendas to deepen engagement with Africa's potential contribution to urban sustainable development transitions, transdisciplinary experiments provide an opportunity for reimagining and reconfiguring urban outcomes. We conclude this paper by reflecting on the three questions posed: What is the significance of transdisciplinary approaches for the delivery of relevant urban outcomes? What role do transdisciplinary research projects play in bridging between local projects and global agendas? Is there a distinctive approach to transdisciplinarity emerging from Africa?

The LIRA projects, responding to the call *Advancing the implementation of SDG 11 in cities in Africa*, demonstrate the value of transdisciplinary approaches for stimulating new evidence on the distinctiveness of African urban transitions, whilst fostering deeper partnership relationships that strengthen governance capabilities for delivery. The uptake of findings and approaches in African cities, with evidence of both structural change and shifts in mindsets, has provided a glimpse into how this scholarship contributes to the science-policy interface, whilst realizing societal benefits. Engaging with the specificity of the “what” and the “how” of urban change across diverse African contexts is particularly significant in post-colonial cities, which are urgently in need of policy reform and reconfiguration of service delivery mechanisms, which that have historically been incompatible with serving the needs of complex communities in informal contexts.

In translating global goals to the local level, “one size fits all” best practice approaches are not appropriate. Each project demonstrated unique and contextually derived approaches. The significance of engaging deeply with local contexts and constituting and nurturing relevant project teams clearly demonstrated that there will be multiple African urban futures. The focus on both scientific and societal goals in action-oriented transdisciplinary endeavors is significant. These dual goals, driven by local priorities, stimulate innovation in methods of engagement, knowledge integration, and in policy and service delivery tools and infrastructures. The potential of

transdisciplinarity to contribute positively at the science-policy interface is demonstrated through the contribution made to generating data on cities and thus facilitating evidence-based policy development. In parallel, approaches and outputs used for meeting societal goals have deepened relationships and trust, with implications for shifting actions to support policy change. These projects therefore simultaneously address the conceptual and delivery deficits in local areas; whilst highlighting blind spots in global policy agendas that are misaligned to the complexity of African cities.

Finally, the study begs the question of whether or not a uniquely African approach to transdisciplinary research is emerging. Whilst there is insufficient evidence to make definitive claims, it is important to acknowledge the significant contribution made by LIRA scholars to shifting the political economy of research on Africa, by destabilizing the dominance of research on the continent by scholars from the global North. The extent of uptake of findings and approaches, with evidence of structural change and shifts in mindsets is providing a glimpse of the potential that investments in transdisciplinary research can have for realizing relevance through research in African cities.

DATA AVAILABILITY STATEMENT

The data is held by the International Science Council. Requests to access these datasets should be directed to katsia.paulavets@council.science.

AUTHOR CONTRIBUTIONS

ZP was the lead of the LIRA Project Level Learning Study. FS was the lead of the LIRA Programmatic Level Study. KP was the PI of the LIRA programme. All authors contributed to the article and approved the submitted version.

FUNDING

This study was funded by the Swedish International Development Cooperation Agency (SIDA) and delivered through a partnership between the International Science Council (ISC) and the Network of African Science Academies (NASAC).

ACKNOWLEDGMENTS

The authors acknowledge the contributions from all Principal Investigators who contributed to this study, and Saskia Greyling (University of Cape Town) and Stefanie Burkhart (Goethe University) who provided support in the preparation of this article.

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Conflict of Interest: KP was employed by International Science Council.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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