Facilitating Urban Sustainability through Transdisciplinary (TD) Research: Lessons from Ghana, South Africa, and Zimbabwe

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Abstract: The notion of sustainability has been integrated into many aspects of development to emphasise human needs now and in the future. Sustainable urbanization objectives are pertinent in the context of rapidly expanding African cities, in which urban inhabitants experience challenges associated with poor sanitation, climate hazards, and energy and food insecurity. There are increasing calls for embracing transdisciplinary (TD) research for mapping pathways towards sustainability in these ever-growing cities, particularly by integrating academic, practitioner, and societal knowledge to design effective and contextually relevant responses to existing and emerging challenges. Though transdisciplinary processes are growing in developing countries, dispersed literature on and a growing number of projects applying TD research in different contexts make it difficult to learn from and develop useful frameworks for implementation. To make lessons more accessible to a growing audience, this paper provides a reflective account of two urban sustainability TD projects that were designed and implemented in Ghana, South Africa, and Zimbabwe. The contexts within which these TD research projects took place are described, as are ways in which relevant stakeholders were involved in and benefitted from the codesign and realisation of the respective projects. Based on experiences, the paper reflects on the challenges of and opportunities for TD research in Africa for urban sustainability, which provides insights for enhancing this practice in Africa. The paper ends with considerations for TD practice and theory.

Keywords: transdisciplinarity sustainability; codesign; challenges; opportunities

1. Introduction

African cities are growing at a rapid rate, characterised by “agile informal settlements” and “multiple ecologies” [1]. A large portion of urban inhabitants experience challenges associated with poor sanitation, climate hazards, and energy and food insecurity. There are increasing calls for embracing transdisciplinary (TD) research for mapping pathways towards sustainability in these ever-growing cities, particularly by integrating academic, practitioner, and societal knowledge to design effective and contextually relevant responses to existing and emerging challenges [2–4]. We acknowledge the multiple theorisations related to sustainable cities and embrace the definition that sustainable cities are those that meet the needs of urban inhabitants without the unsustainable exploitation of resources and systems [5]. Although the importance of TD approaches is increasingly recognised in promoting sustainability in African cities, coproduction processes involving the participation of a wide range of actors have neither been well documented nor systematically analysed in developing urban contexts. In cases where TD approaches are interrogated,
much of the work has been on concepts [6] rather than reflection on local TD experiences, with a few notable exceptions [7]. Furthermore, while lessons from implementing TD research have been documented, few lessons are based on a systematic and comparative analysis of experiences in different settings. Recognising the multiple conceptualisations of TD research, here we consider it as researchers engaging societal stakeholders from the problem space in research.

There is a small but growing body of literature on transdisciplinary codesign and coproduction of knowledge in African cities to promote sustainable urban transitions [4,8,9]. The available knowledge on TD research and practice is, however, still skewed by the many studies that have been implemented and documented in developed countries. Reflections on TD planning and processes from the perspectives of African researchers are even less prevalent, except for a few exceptions [4]. It is important that young African perspectives are reflected in critically interrogating and providing empirical evidence associated with TD research.

In this paper, we provide a reflective account of two TD projects that were designed and implemented by teams of researchers within the broader framing of the Leading Integrated Research for Agenda 2030 in Africa (LIRA2030) to address complex African urban sustainability challenges. LIRA2030 is a 5-year programme that has aimed to support the production of “high-quality, inter- and transdisciplinary, solutions-oriented research on global sustainability by early career scientists in Africa” (https://council.science/what-we-do/funding-programmes/lira2030/, accessed on 29 May 2021). Drawing on experiences from early career researchers in Ghana, South Africa, and Zimbabwe, the paper examines the societal impacts, successes, and challenges of implementing TD research. These aspects are assessed by reflecting on empirical evidence through the lens of the outcomes spaces framework (OSF) [10]. Drawing on this framework, the study is guided by the following questions: what was the expected improvement for the situation in the projects and what assumptions were implicit (or explicit) in project design; what stocks and flows of knowledge were generated; and what collaborative, inclusive, and reflective practices supported mutual learning among participants? Evidence includes stakeholders’ experiences of TD research in practice (codesign and knowledge coproduction for sustainable cities); the challenges, opportunities, and successes emerging from experiences; and how these compare across different African cities that were involved in the abovementioned two LIRA2030 projects.

Reflecting on the experiences and outcomes of TD research applied in different African cities and examining expectations against actual practices and impacts through the OSF change theory framing is useful in various ways. First, it allows for reflections on TD assumptions about achieving societal impact and the interrogation of expected pathways towards impact, with adjustments where necessary. Second, at a practical level, it can contribute to a framework for collaboratively considering problems being tackled through TD research, as well as expected beneficiaries of this research. Third, reflections on the challenges of and opportunities for TD research and practice from researchers’ experiences can provide key insights for grounding and promoting this approach. More broadly, it allows lessons to be gleaned for deepening TD practices and theorizations in an African urban context. In doing so, insights into pathways towards African urban sustainability are provided.

1.1. Background Theory
1.1.1. The Urban Sustainability Challenges

Humanity faces many challenges associated with increasing patterns of production and consumption, depleting natural resources, and growing inequality within and between societies [2,10]. The notion of sustainability, which emphasises the importance of considering human needs now and in the future, has been introduced into almost all aspects of development, including business, policy, and research [11]. This concept is normative in nature, ethically loaded, complex and contested [10–13]. Contestations relate to the
power differentials between groups of people and issues of inclusivity during processes of defining sustainability goals, as well as the complex and connected nature of sustainability issues, which generally span physical spaces, time, and knowledge domains [13]. Such contestations are highlighted in discourses related to the 17 Sustainable Development Goals (SDGs), which were established in 2015 and represent the most significant effort towards achieving and measuring sustainability at various scales across the globe [14,15].

Elmqvist et al. [14] argue that all SDGs have some level of dependency on urban sustainability. Urbanisation is one of the most “dramatic and permanent” land-use change processes, presenting both opportunities and challenges for achieving sustainability [2] (p. 261). Childers et al. [11] posit that cities have changed in ambition, form, and function as urban goals have evolved from industrial, to sanitary (safe and comfortable for people to live), and more recently to sustainable. An increasing number of city authorities are striving towards the “sustainable city”, though different development trajectories over time has led to huge variation in cities [11]. The variety of landscapes within cities is also notable, particularly in African cities, which are rapidly urbanising and dynamic [1]. Concepts of urban sustainability and sustainable cities are also contested [16]. However, several key features span the literature, including the improved wellbeing and safety of urban communities (including a focus on equity), reduced negative consequences on biodiversity, increased resilience to climate and disaster risks, and low carbon development [11,16,17]. Childers et al. [11] argue that working towards sustainable cities requires: (i) appreciating this work as an ongoing process instead of an end goal; (ii) integrating scientific knowledge on cities as complex systems; (iii) understanding various constraints and emerging modes of governance; and (iv) including urban design and planning ideas.

1.1.2. Theorising TD Research

Sustainability science has evolved alongside a growing acknowledgement of the importance of sustainability, particularly related to urbanisation [11]. A crucial aspect of sustainability science, which aims to contribute knowledge for dealing with complex and contested sustainability issues, is the participation of societal stakeholders and collaboration between different knowledge domains [13]. Transdisciplinarity (TD) is one such mechanism. Transdisciplinarity (TD) is one such mechanism. Transdisciplinarity insists that research is situated in context, and that research questions respond to wicked societal problems [13,18,19]. TD processes facilitate new ways for multiple stakeholders to work together across paradigms for knowledge transfer, translation, and ultimately transformation in the form of novel responses [20,21]. In this way, TD research aims to coproduce socially robust knowledge and/or services. Transdisciplinarity is generally separated from other modes of producing knowledge—including disciplinarity, multidisciplinarity, interdisciplinarity, and cross-disciplinarity—because of the focus on knowledge production beyond academic disciplines [22–24].

Definitions and theories of TD research vary and are often contested [12]. Transdisciplinarity has been described as an approach, methodology, process, and theory [13] rooted in different ontologies and epistemologies [23]. Several major “clusters of meaning” and key words are, however, associated with “transdisciplinary momentum”, as described by Klein [18] and presented briefly below.

- Transcending disciplines: Transdisciplinarity is a quest to expand knowledge recognition, production, and documentation beyond the realm of academic disciplines [23], especially to align with real-world problems [25,26]. Transdisciplinary research aims to tackle complex problems from a more holistic, systemic perspective [13,25,27], promoting holistic thinking, crossing, and transcending knowledge boundaries.
- Acknowledging and embracing complexity: Transdisciplinary research moves away from the reductionist approach of breaking large, complex systems into smaller, analysable units, which has typically been applied for understanding problems within disciplines [18,28]. This approach is replaced by a different paradigm that enables emergence, diversity, and heterogeneity and encompasses “assumptions of unpredictability, incomplete control and a plurality of legitimate perspectives” [19,29].
• Valuing participation and collaboration: Collaboration between knowledge holders and integration of different perspectives is a key characteristic of TD research [13]. For example, research processes might include inter alia networks of scientists, experts, and civil society [25].

• Working with and integrating different types of knowledge: With the variety of participants involved in TD research, different types of knowledge are brought to bear on a problem of societal relevance, and to consider responses [27]. Scholz and Marks [30] proposed three broad categories of knowledge associated with the TD process, which were progressed by Hirsch Hadorn et al. [27]: systems knowledge, target knowledge, and transformation knowledge.

• Transformation through transgression: Transgression in TD research occurs through questioning the epistemological superiority of “objective” or scientific knowledge for understanding and explaining complex and wicked human-related problems [13,19,31]. TD research interrogates claims of ‘truth’.

1.1.3. Addressing Urban Challenges through a TD Approach

Cities play increasingly important, intricate, and multifaceted functions in society [32], e.g., they are hubs of economic growth, entrepreneurship, and technological development, and they potentially contribute to poverty reduction and human development [33,34]. In contrast, cities experience complex socioeconomic processes that can result in several urban problems and can become locations of poverty, environmental hazards, and inequality [33,35,36]. Urban challenges often differ between the Global North and the Global South, where the latter has faster-growing urban populations amid poor planning contexts, resulting in complex urban challenges [7]. In many African cities, migration to urban areas in search of better and secure livelihoods, safe living conditions, better healthcare, and educational services is increasing [37]. This has resulted in congested and overcrowded spaces with poor sanitary conditions, slums with poor housing, and inadequate infrastructure, which often leads to outbreaks of communicable diseases [38]. Challenges that residents of African cities face include unequal access to public infrastructure and services (mainly water and electricity), growing inequalities between the urban rich and the poor, insufficient employment opportunities, poor municipal waste management, and challenges related to climate change, e.g., flooding and air pollution. These challenges have the potential to jeopardize Africa’s potential to meet its urban development goals in a sustainable manner. Against the above context, we elaborate on two urban challenges that are common to many African cities and are relevant to the LIRA2030 projects that were assessed in this study.

Climate change challenges in African urban areas: Scientific evidence shows that hazards (e.g., heavy rainfall, heat waves, and droughts) linked to climate change are likely to exacerbate ongoing development challenges, increasing the vulnerability of the urban poor to risks [39]. An increasing frequency and magnitude of climate change risks on African urban dwellers will cause huge costs, both in terms of human wellbeing and finances, for most African governments [1,40]. Appropriate strategies and action plans are therefore required to increase the resilience of African cities and their residents in the face of climate change. The complex nature of climate change risks (i.e., how they manifest across different urban landscapes and various urban communities over time) makes TD an appropriate approach to better understand climate-related challenges, and to respond to climate change complexities using collaboratively developed and contextually relevant interventions.

Energy use challenge in African urban areas: Energy, notably electricity, is central to the functioning of urban systems and is regarded as the life blood of urban economies [41]. The increased rate of urban migration to African cities coupled with the lack of capacity by most governments to deliver services has resulted in inadequate energy provisioning, escalating energy costs, inefficient energy use, and ultimately socioeconomic problems in many places [42]. Multiple challenges associated with energy access in African cities
have been noted including inter alia: (i) insufficient power generating capacity; (ii) poor management of existing energy infrastructure; (iii) low investment in the energy industry; and (iv) booming urban population resulting in increased demand for energy [43]. Given these challenges, most poor households in African urban areas do not have access to electricity, particularly in informal settlements.

Considering the complex and dynamic nature of these challenges, TD is considered an appropriate approach that allows multiple urban stakeholders to collectively grapple with contextual challenges, and coproduce knowledge towards responses [4]. There are, however, large gaps in understanding how concepts and methods associated with TD research that have been constructed in developed country contexts transpose onto a developing country context, more specifically an African urban context. Emphasising the “high levels of complexity, conflict and social fluidity”, van Breda and Swilling [3] warn of the assumptions implicit in TD approaches that have been documented in a developed country context. For example, the erroneous assumptions that diverse stakeholders involved in TD engagements engage on “equal footing” and in formalised settings, as might be the case in developed country contexts [3]. For this reason, TD research and practice in African cities requires deeper consideration and documentation to contribute to the body of available, relevant knowledge and support learning within the community.

2. A Framing for Reflecting on African Urban TD Research

The process of reflection is distinctly different from impact evaluation. The former supports lengthier and deeper considerations that allow for adaptive learning, while the latter generally involves judging an intervention or activity against a set of predefined criteria [44,45]. Here, we reflect on TD research and practice in the context of relatively novel ‘experiments’ aimed at contributing to science–society relationships to deal with urban sustainability issues [45] in four African cities.

To reflect on TD research projects that have been implemented in African urban contexts, the outcomes spaces framework (OSF) was applied [12]. The OSF provides a useful framework for analysing three key, interlinked areas associated with TD research, namely: expected improvement in the situation, generation of stocks and flows of knowledge, and mutual learning between stakeholders. Expected improvement in the situation relates to impacts in the social context of the study. For example, these might include the development of a strategy or changes to policy to integrate appropriate responses to risks. According to Mitchell et al. [12] this shows a departure from designing “solutions” due to the complex and messy nature of the problems with which transdisciplinary research processes deal with. Regarding the generation of stocks and flows of knowledge: Meadows [46] defines stocks as elements of any system that can be seen, felt, measured, or counted at any given time and forms the foundation of that system. Stocks of knowledge relate to the knowledge outputs produced through TD research. Mitchell et al. [12] describe how flows of knowledge are equally as important as the stocks of knowledge that are produced within the various processes (e.g., disciplinary research processes or transdisciplinary activities). Purposive and effective transdisciplinary research should include flows of knowledge between disciplines, between theory and practice, from inside the bounds of the project to spaces outside, etc. In this study, our focus is on flows of knowledge between theory and practice through active involvement of academic and nonacademic actors. Mutual learning between research participants is expected to take place between participants of the transdisciplinary research processes, including scientists, practitioners, and policy makers, among others. This type of learning is facilitated by collaborative, inclusive, and reflective practices that provide spaces in which multiple worldviews can be expressed and differences are appreciated [12]. It is also dependant on the interactions and relations between different groups of people (e.g., in learning labs). Mitchell et al. [12] emphasise the importance of the “quality” of dialogue for this type of learning.

The OSF framework also enables reflection on assumptions associated with expected impacts or changes. Adopting an epistemologically pluralistic approach to knowledge and
knowledge coproduction, the framework cuts across the many definitions and theories associated with TD research, the affinities to which varied across the research teams and participants [10]. Based on the OSF, we reflected on TD experiences for 12 variables that were common in two LIRA projects (Table S1).

2.1. The Case Studies

The study drew on evidence-based reflections from TD projects in Ghana (Kumasi), South Africa (Durban and Makhanda), and Zimbabwe (Harare) under the auspices of LIRA2030. Project interventions were implemented within two broad projects supported by the LIRA2030 programme: (i) LIRA project 1 “Transforming southern African cities in a changing climate” focusing on Durban and Harare; and (ii) LIRA project 2, which was implemented in Makhanda and Kumasi, entitled “Household energy use practices and potential interventions for sustainable consumption” (hereafter LIRA project 1 and 2) (Table 1). Both LIRA projects, implemented across four cities, employed TD approaches to understand and promote urban sustainability in different socioeconomic settings. The key realms of OSF as suggested by Mitchell et al. [12] are comparable across the cities, given that similar TD approaches were applied. Despite varied cultural, political, social, and environmental contexts, the cities of Durban, Harare, Kumasi, and Makhanda have several socioeconomic and environmental challenges that are common across urban areas in Africa.

Table 1. Overview of the two LIRA projects.

| Characteristic                              | LIRA Project 1: Transforming Southern African Cities in a Changing Climate (2019–2020) | LIRA Project 2: Household Energy Use Practices and Potential Interventions for Sustainable Consumption in Makhanda, South Africa and Kumasi, Ghana (2019–2021) |
|--------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Sustainability challenge being addressed   | Failing to address climate change effectively will seriously undermine efforts to meet the targets of SDG11: to make these cities and settlements inclusive, safe, resilient, and sustainable. | Unsustainable electricity use at the household level in Kumasi and Makhanda. Current electricity saving arrangements by the power utilities in Ghana and South Africa are externally driven with negligible involvement of households. |
| Main objective of the project relative to knowledge coproduction | Coproduce knowledge on transformative climate adaptation in the context of Durban by identifying and assessing potentially transformative interventions | Codesigning user driven energy saving interventions for sustainable household electricity use |
| Project duration                           | 2.5 years                                                                              | 2 years                                                                                                                          |
| Led by                                     | South African academic at University of Cape Town                                       | Ghanaian academic at Kwame Nkrumah University of Science and Technology                                                        |
| Main societal stakeholders involved        | Local city authority                                                                   | Local residents and project champions                                                                                         |
| Other societal stakeholders                | NGOs, CSOs, community representatives                                                  | Electricity company of Ghana                                                                                                   |
| Main method(s) implemented                 | Transdisciplinary learning labs, interviews, site visits, visits from Harare exchange team | Workshops, household surveys, formal and informal meetings                                                                      |

Durban, with more than three million people, is the capital of KwaZulu-Natal province and the third most populous city in South Africa. The city is home to the largest and busiest port on the east coast of Africa [47]. The Durban municipal areas cover approximately 2300 km², and the city’s economic activities are driven by finance, community services, and manufacturing [48]. Durban experiences a subtropical climate of hot and wet summers, with mild and dry winters [47]. It has been praised as a city that has adopted a climate...
change adaptation agenda relatively early, while many other cities focused on mitigation [49]. A sizeable population in Durban lives in informal settlements and experiences challenges associated with development deficits, environmental degradation, poverty, and growing urban inequality [48,50]. Under conditions of climate change, vulnerable urban communities and infrastructure are expected to experience an increased frequency and magnitude of flood risks, which already pose a significant threat [51].

Harare is the capital city of Zimbabwe, with a population size of approximately 1.5 million people. The city covers ~960 km\(^2\) and experiences a subtropical climate characterized by hot and wet summers and cold and dry winters. Although Harare is Zimbabwe’s leading financial and commercial hub, the city’s economic activities have been severely affected by the political instability and economic crises that have plagued the country for nearly two decades. Since 1980, migration to Harare has been increasing, resulting in growth of urban populations, though anecdotal evidence suggests deurbanization due to economic hardships in the city and migration to neighbouring countries [52]. The challenges facing Harare city include poor infrastructure, urban poverty, high unemployment, poor governance, and growing inequality. Water supply is already a challenge in the context of outdated, degraded infrastructure and increasing urban populations. Potential climate change impacts will likely increase challenges associated with water resources for Harare.

Kumasi is the second largest city in Ghana, with a population of approximately three million people. It is the capital and administrative city of the Ashanti Region and the traditional capital of the Asante kingdom. The Kumasi metropolis has a land area of approximately 254 km\(^2\), and the city experiences a wet semiequatorial climate. The city owes much of its economic growth to the commercial activities, principally wholesale and retail activities. Its central location makes the city a key transport and commercial hub within the West African trade region. The economy is also boosted through the manufacturing activities of the central mechanic workshop—Suame Magazine—and timber and cocoa industries associated with the forest region of Ghana [53]. The city has attracted wide and diverse migrants from Ghana’s rural areas and other African countries, which has laid bare urban challenges, including limited employment and livelihood opportunities, poor housing development, and erratic electricity supply [54].

Makhanda, formerly Grahamstown, is a medium-sized town of approximately 70,000 people, located in the Eastern Cape Province of South Africa. The town has a mean temperature of about 27 °C in summer (October–March) and 19 °C in winter (May–July) months. Mean annual rainfall is about 600 mm per year, with peaks in the summer months October and November and March and April due to frontal rainfall [55]. Two major climatic systems converge in the Makhanda region resulting in relatively high temperatures and evenly distributed precipitation throughout the year. Makhanda’s land size is approximately 65 km\(^2\), and the economy of the town is driven by the education sector, namely Rhodes University, public schools, and a few historically white elite private schools. Migration of people from nearby farms and Makhanda peripheral villages to the town is a historical issue as people search for economic opportunities and improved service provision. This has seen an increase in Makhanda’s informal settlement populations and a decline in municipal services delivery as the local government fails to cope with urban growth. In general, the town is characterised by high levels of poverty and unemployment, low literacy levels, and limited access to basic infrastructure and services [56].

2.2. Reflections Across the Projects

The breadth of experiences in the different LIRA projects and sites are shaped by the main societal stakeholders involved and the socioeconomic and political contexts of the respective projects.

2.2.1. Improvements in the Situation across the Two LIRA Projects

Framed within the broader LIRA2030 programme, the two LIRA projects acknowledged the need to solve African urban sustainability challenges through science–society
partnerships and working with multiple stakeholders, as a basis for coproduction of knowledge and mutual learning. The desired change of LIRA project 1 was to coproduce knowledge that would support pathways towards transformative adaptation in Durban and Harare as a response to climate change that promotes equality, inclusiveness, and justice. The desired change for LIRA project 2 was to promote transition to sustainable household electricity use through collaborative knowledge generation between community members, power utilities, and local government officials with academics as knowledge intermediaries.

The key assumption in both LIRA projects was that engaging all stakeholders in formulating the research problem would ensure a collective effort in the codesigning and implementation of interventions that are relevant to the respective stakeholders’ contexts and priorities [47]. The desired changes in the situations were articulated near the beginning of both projects across the cities [10].

LIRA project 1 leveraged existing collaborations that were established through the Future Resilience of African CiTies and Lands (FRACTAL) project (www.fractal.org.za accessed on 29 May 2021). The core research teams were therefore familiar with each other, which contributed to effectively working together from the beginning. Partnerships that were strengthened included those between all university partners in Cape Town, Durban, and Harare, as well as between the local universities and respective local authorities in Durban and Harare. Several new partnerships also emerged within the cities including between researchers involved in LIRA project 1 and the C40 Finance Facility, which was implementing work on transformative river management in Durban (https://www.c40cff.org/projects/ethekwini-municipality-durban-transformative-riverine-management-programme, accessed on 15 August 2020), and between the local university in Harare and the Harare Wetlands Trust. These new partnerships opened new, ongoing channels of communication across stakeholder groups, which were initially supported during the transdisciplinary learning labs in Durban and Harare.

Evidence suggests an ongoing impact of knowledge that was coproduced in Durban and Harare, particularly focused on improving ecological infrastructure” through community-based engagement as a means of reducing climate-related risks. The “principles” of transformative adaptation that were coproduced with participants in Durban have been integrated into the design of the ongoing Transformative River Management Programme (TRMP), while the local authority in Harare is considering implementing a similar programme to formally support stewardship management of waterways and wetland areas. One of the project participants in Durban added the concept of “transformative adaptation” on their departmental meeting agenda, based on knowledge gained from meetings. In Harare, the knowledge generated during LIRA project 1, together with FRACTAL, in part triggered discussions around setting up the climate change desk. Despite these positive changes in the situation, reflections on LIRA project 1 highlighted two challenges that have implications on outcomes: (i) the private sector, which is an important stakeholder in reducing risks, was missing from engagements; and (ii) local communities were represented by very few individuals (those who could speak English and engage with the fairly technical content).

The collaborations that were set up with societal stakeholders in LIRA project 2 shifted traditional boundaries and dynamics. Researchers worked with different types of societal stakeholders to identify influential individuals relevant to the project theme, as well as constraints faced by local households in accessing electricity. For example, one of the societal stakeholders in Makhanda was a former local councillor who helped the researchers understand and navigate the complex political and social structures within communities. Partnering with local residents in Makhanda resulted in the collection of information on current electricity use practices and challenges. Several project engagements also allowed for the alignment of research goals with the local and contextual realities. The transdisciplinary processes supported a shared understanding of the sustainability challenge and the development of societally relevant and user-driven electricity saving interventions. In
Ghana, the Assembly members and the Unit Committee, which constitute the fundamental unit of the local government structure at the community level, facilitated community entry. In other communities, the traditional authorities were the first points of contact. Such processes allowed researchers to connect scientific questions and practices to community priorities and needs. Almost all participants of the LIRA2030 transdisciplinary engagement in Kumasi took it upon themselves to share knowledge about interventions that were conceptualised during the LIRA project 2 that they had gained from the engagements with other households.

In their roles as knowledge intermediaries, researchers also supported shifts in the nature of engagements between communities and local authorities in Makhanda and Kumasi: from “fault-finding” to a more collaborative approach. Near the beginning of early engagements, community champions were primarily motivated to share frustrations of households (e.g., faulty electricity meters, free electricity provision, and concerns on electricity prices). Researchers carefully guided conversations towards the project goals of cogenerating useful knowledge to deal with these challenges, supporting behaviour change, developing agency, and building bridges between stakeholders [4].

In both Makhanda and Kumasi, collaboration among partners improved over time as a shared understanding was developed and trust grew between stakeholders who had not historically worked together. For example, community champions in Makhanda were responsible for facilitating one of the workshops with participant households in the area to share experiences related to implementing electricity-saving interventions. These champions exhibited leadership and confidence during this workshop. In Kumasi, participants strongly advocated for the project team to extend their engagements beyond the lifespan of the project, stating that these had supported relationships that the ECG and Energy Commission had historically been trying to support unsuccessfully. The project fostered partnerships between the utility agency and the communities despite a history of the two partners’ disagreements on many issues.

In both projects, these experiences align with transdisciplinary literature on the importance of establishing partnerships, relationships, and a shared understanding of the sustainability challenge, as well as aligning local priorities with research interests and engendering common interest among stakeholders [24,57]. Much has also been written about the time and resources required to undertake these additional relational activities [58].

The experiences related to working with multiple partners and engendering relationships for coproducing sustainability knowledge have several implications for TD theory and practice in African urban settings. First, the experiences that have been documented highlight the complexity of local challenges that should be considered in project design, particularly when these activities are implemented in centralised settings. In such settings, collaborative leadership is important and strong relational capacities are required. Related to this point, appreciation of the variety of roles played by stakeholders, including championing, is a key enabler for TD practice. Furthermore, bringing multiple actors together can result in misaligned priorities, which can undermine TD research. Thus, TD projects should anticipate tensions, and design mechanisms for managing them. Drawing on our experiences, we argue that while the involvement of multiple partners is necessary, trade-offs constantly need to be made related to who to involve when, and through what means especially when time and financial resources are constrained.

2.2.2. Knowledge Stocks and Flows

Building knowledge stocks and flows in Durban and Harare involved several transdisciplinary engagements and exchange activities, with a strong emphasis on knowledge coproduction. Disciplinary knowledge that was generated through research was shared at learning labs, during which participants could interact and influence the outcomes of the research. Opportunities were also provided for stakeholders from Durban and Harare to engage with knowledge that was coproduced in the other city contexts. For example, a documentary on transformative river management that was produced based on the
Durban case studies was screened at the Harare learning lab. The societal stakeholders who were involved in coproducing knowledge in both cities included civic organisations, local government and academia, multilateral agencies, practitioners (hydrologists and engineers), NGOs, and national government. The research team included diverse disciplines, ensuring rich knowledge from different fields including social science, environmental science, ecology, and practitioner experience.

In both cities, there was discernible flow of feedback in a two-way approach from the project team to city stakeholders, and vice versa. For instance, the aim of the last learning labs in Durban and Harare was to share findings from the research and to integrate stakeholder comments into final knowledge outputs. Reflection exercises were included at the end of each engagement to gain a deeper understanding of the value of these spaces for societal stakeholders. These reflections improved the knowledge held by the LIRA project 1 research team with regard to effective transdisciplinary research. Knowledge outputs from the LIRA project 1 were variable to appeal to a wide range of audiences. Processes were implemented to be sure that the outputs that were produced were relevant and usable in the decision-making context of Durban and Harare. For example, stakeholders in Durban prioritised key learning themes that had emerged during the project for in-depth discussion at the last learning lab and for the production of knowledge outputs based on the “usefulness” of the themes for their work. These stakeholders also selected their preferred format of knowledge product. A session was included in the last learning lab in Harare for participants to brainstorm important learning themes to be shared with a wider audience, as well as the most effective knowledge output from the project in their local context (a policy brief). Knowledge was also documented through lab reports, which were shared with participants after each event, as well as journal articles that were being written at the time of this study for an academic audience.

The exercises that were facilitated at the beginning of the engagements for both cities allowed societal stakeholders to explicitly engage with transdisciplinary ethics. These exercises opened a space to challenge dominant narratives related to what constitutes robust knowledge in line with societal contexts [12]. This move towards coproduction as opposed to traditional disciplinary knowledge has the potential to influence new modes of knowledge creation to deal with African urban sustainability challenges. The projects shifted the flow of knowledge from the traditional “top down” academic to society flows to a bottom-up engagement consistent with TD principles [12].

In Kumasi and Makhanda, engagements that contributed to stocks and flows of knowledge included workshops with community champions and residents, as well as direct meetings with city officials and power utilities. Information flowed across stakeholder groups and community champions and residents, who were the main societal stakeholders involved in the codesign of electricity-saving interventions, providing reflections on the ease of engaging with the content, as well as the usefulness of interventions into the future. Different stakeholder groups were also invited to take part in conversations that occurred after this envisaging process, some of which had not previously engaged with one another. Knowledge was packaged into interventions booklets, a documentary, and academic papers, enabling a variety of audiences to engage with the content. A diverse research team comprised academics, community champions, residents, and, to a lesser extent, ESKOM. There was evidence of collaboration between the municipal authorities, communities, and electricity providers on knowledge coproduction and sharing on current electricity use practices and perceptions, as a basis for developing a shared understanding of the sustainability challenge and the value for collectively responding to the challenge.

Klein [18] asserts that TD research aimed at creating change requires varied knowledge from different sectors and stakeholders and knowledge forms, including those that were once excluded. In some instances, dominant paradigms related to the superiority of academic knowledge need to be challenged to integrate these various types of knowledge. Similarly, Mitchell et al. [12] emphasise the need for appropriate and purposeful “housing” of knowledge products to ensure the desired change.
2.2.3. Transformative and Mutual Learning

Reflections on LIRA project 1 suggest that the transdisciplinary learning labs supported transformative and mutual learning for several groups of stakeholders who were involved through activities and processes aimed at constructing knowledge and facilitating social learning. This is partly a design feature of the learning labs, which created the space to understand the problem/situation from many perspectives, formulate key questions by collaborators related to drivers of risks, and consider pathways to more transformative approaches to climate change adaptation by collaboratively interrogating several ongoing interventions [49]. Dialogues and interactive exercises, in which stakeholders participate actively, were key in the transdisciplinary labs. Evidence suggests that these learning activities resulted in better, more holistic understandings of the complex nature of water risks that will likely worsen under conditions of climate change for many stakeholders. The implication of this understanding is the acknowledged need to continue to involve multiple stakeholder groups in considering interventions that might improve the situation. The labs also supported the conceptualization of what transformative river management (to address poverty and climate risks) looks like in Durban: the varied governance approaches and benefits of these. Participants of learning labs also seem to have acted in daily living that directly seeks to address some of the drivers of risk.

Similarly, evidence suggests mutual learning for several groups of stakeholders in LIRA project 2. Workshops with energy champions further facilitated peer-to-peer learning processes. The project provided opportunities for learning through hosting regular formal and informal meetings between researchers and local community champions. For example, through workshop interactions, participants discussed the energy challenge beyond just a household problem and framed it, rather, as a community problem. Where appropriate, researchers and energy experts provided advanced scientific training to energy champions (e.g., data collection tools and interpretation of technological electricity-saving interventions). A key mutual learning opportunity emerged when energy champions visited participating households to share information with families and small groups. This approach opened new avenues to understanding the electricity use problem, e.g., the identification of barriers to savings and the identification of appropriate and relevant interventions. Champions played a key role in the learning process, facilitating the one-on-one household visitations and small group meetings.

In both LIRA projects, mutual learning happened through collaboratively identifying and understanding the problem, questioning the nature of the problem, generating interventions, and practically applying them to build new capacities [59]. This adds weight to the importance of conceptualising project design as a social process which is claimed to focus less on providing expert solutions but allows for the bottom-up engagement and involvement of a broader range of stakeholders [57]. Participation in learning labs and workshops facilitated social learning from one another through discussions, reflective learning through reflections on project experiences, and learning by doing the project. We view the coproduction of practical knowledge that improves the situation by collaborators in both LIRA projects as an indication of mutual learning. For example, stakeholders in Durban expressed interest in attending learning lab platforms in the future so that they continue to gain knowledge from multiple perspectives and connect with other societal stakeholders. In Harare, the suggested establishment of a climate change desk within the Town Clerk’s office was supported by learning that took place during transdisciplinary labs, alongside the FRACTAL project, and the local authority remains committed to involving a broader range of societal stakeholders in the climate adaptation agenda. Several stakeholders experienced key learning related to improving “ecological infrastructure” in these cities through community-based engagement as a means of reducing climate-related risks. Our experiences illustrate value in shifting project design from the perspective of problem-solving to problem formulation agendas [57,60]. In our case this engendered a collective point of departure and ensured that resources and processes were channelled towards addressing the problem (sustainability challenge).
In LIRA project 2, workshops allowed collaborators to gain insight into factors that constrained participants in implementing energy saving interventions. For example, workshop participants highlighted that energy saving interventions were useful but insufficient if they did not include the “backroom” households, which are attached to the main households and the electricity supply but are rented out to different families. This realisation was further strengthened through one-on-one household visits, and these lessons have implications for TD research in an African urban context. For example, the LIRA project 2 team has reflected on the importance of building a good understanding of household profiles, which provide critical information (knowledge stocks) about how people live and how households interrelate. This understanding supports the development of contextually relevant interventions that are more likely to contribute to meaningful changes. The willingness of workshop participants to share information about “backroom” households is testimony to the trust that was developed over time. The increasing role of local champions (who are members of the local community) in facilitating these workshops in their local language also suggests learning and encouraged active involvement by participants who were able to express their views on energy saving interventions without reservations. All participants of LIRA project 2 felt there was willingness to engage in collaborative learning and decision making and strongly agreed that stakeholders listened to one another: that their ideas and views informed the project goals.

One of the key challenges for mutual learning across the two LIRA projects related to a limited awareness of the problems, resulting in a misalignment of perceptions regarding the nature of the problem. Often, stakeholders experience problems in different ways: this diversity of perspectives is a strength of TD research but should be managed carefully to ensure productive engagements [61]. For example, in LIRA project 2, differences in views regarding whether the energy problem is a community or household challenge and whether the energy problem was caused by the inefficiencies of the utility agencies or by the behavioural dispositions of the users impacted learning about the problem and the development of effective solutions. To overcome this challenge, workshops were hosted to jointly develop guiding questions that helped explore this tension. A second challenge faced in both LIRA projects relates to the influence of power dynamics and asymmetries on participation and learning in TD. For example, researchers have historically been seen as playing the role of knowledge provider, and societal stakeholders might not freely contribute to dialogue following input from these collaborators. Power asymmetries were also noticed between different groups of societal stakeholders.

In both LIRA projects, emphasizing project ownership from the beginning as well as providing incentives (e.g., transport and food) during learning labs and workshops encouraged participants to attend TD events. Both transformative and mutual learning are key expected outcomes of transdisciplinary research [12,62]. The experiences gained in transdisciplinary research should result in collaborators gaining new knowledge, perceptions, orientation and strategies that result in them seeing and doing things differently [62]. A summary of reflections across the project is provided in Table 2 below.
## Table 2. A summary of reflections across the case studies.

| Case Study | Changes in the Situation | Stocks and Flows of Knowledge | Mutual and Transformative Learning |
|------------|--------------------------|-------------------------------|-----------------------------------|
| **LIRA project 1:** Durban and Harare | • Strengthened partnerships between universities, and between universities and municipalities in both cities.  
• Strengthened relationships between a variety of stakeholders in both cities.  
• Codesigned principles integrated into the design of the Transformative River Management Programme in Durban.  
• Strengthened link between ecological infrastructure, urban societies and climate risks.  
• Increased awareness of transformative adaptation in both cities.  
• Supported the setting up of the climate change desk in Harare (alongside FRACTAL). | • Two-way flow of knowledge between stakeholders and research team to influence project design and outputs.  
• “Traditional” flows of knowledge challenged.  
• Documentary on transformative river programmes in Durban produced and shared with stakeholders in Harare and beyond.  
• Coproduced knowledge packaged into academic papers. | • Understanding complex urban risks from multiple perspectives.  
• Acknowledging the value of knowledge held by peers in designing responses.  
• The need for different approaches across the heterogeneous African urban landscape |
| **LIRA project 2:** Makhanda and Kumasi | • Shifted boundaries and dynamics between stakeholders relevant to electricity access to more collaborative approaches in both cities.  
• Increased trust amongst stakeholders in both cities.  
• Increased knowledge of interventions for electricity access (and sharing of this) amongst communities in Kumasi.  
• Increased understanding of the Energy Commission in Kumasi of community issues | • Two-way flow of knowledge between stakeholders and research team.  
• Project knowledge packaged into intervention booklets, documentary, and academic papers. | • Understanding the energy problem as a community problem (instead of household).  
• Increased understanding of the barriers and opportunities for energy saving interventions. |
3. Towards a Robust Understanding of TD Research in African Cities

African cities face complex sustainability challenges, and options for addressing these lie in employing research approaches that allow for the alignment of research questions and local priorities and needs. Due to the complexity of sustainability challenges, and in turn, the need for problem-driven and solution-oriented pathways to addressing the challenges, TD research is desirable because it engenders the participation of multiple stakeholders, considers multiple viewpoints, and allows for the collective generation of knowledge, thereby bridging the research-implementation gap. TD research also satisfies the transformative agenda of sustainability science due to its principles of social inclusion [24]. Our collective but diverse experiences of conducting TD research in African cities highlight important lessons for deepening and enhancing TD research theorization and practice, respectively.

First, our experiences suggest that asymmetrical power dynamics between and within partners matter and can influence outcomes, consistent with findings elsewhere [61]. Building bridges between partners is one of the key outcomes of TD research, but this, paradoxically, means that partners wielding different levels of power and with multiple and conflicting interests might come together. For example, some partners might hold or be perceived as wielding more power due to their political position, (for example, a councillor) or because they work in a university [4]. This can be a source of conflict and could constrain collaboration and opportunities for mutual learning. Therefore, codesigning TD projects whose outcomes and outputs are in line with the needs of multiple partners requires consistent extensive consultations and engagements with partners. Our experience in the different contexts suggest that the processes of “levelling the playing field” or “placing every partner on an equal footing” can result in huge transaction costs in terms of financial, time, and intellectual resources needed [58,61]. This, however, should be considered an acceptable trade-off, given the indications of successful improvement of the situation, significant knowledge flows, and mutual learning.

Second, building relationships with partners is important but challenging. Relationships can be shaped by historical and cultural contexts. For example, a deep-rooted history and experiences of exclusion, economic dependencies, and perceptions of the domination of certain groups based on education, gender, or race can underlie a relationship, which can undermine trust and sincerity in participation. In attempting to bring diverse partners together, TD practitioners should consider acceptable ways for supporting the participation of all partners, including those historically marginalized. In the case studies, conducting a series of formal and informal meetings with societal actors and opening spaces for historically marginalized partners to share information yielded positive effects. For example, it allayed negative perceptions that some partners were more important than others. Previously marginalized actors contributed to shaping questions that aligned research with their goals, demonstrated ownership of problems, and codesigned solutions. Our insights also highlight that while it is desirable for everyone to participate in TD research, time, practical realities, and financial resources make this difficult. Therefore, thinking about what can and cannot be achieved, and who can and cannot be invited, in a relatively short TD research project is crucial to allow meaningful and directed engagement. Decisions about which partners mattered most in the case studies was based on needs and potential benefits.

Third, relational aspects of respect and trust are key ingredients for fostering participation of all stakeholders because “they relate to how partners interact and respond to each other and people’s positionality in relation to each other” [61]. These aspects are invisible and harder to measure than knowledge outputs because they are characteristics of interactions. TD processes require partnership arrangements with clearly defined rules of engagement and agreements that govern structure, processes and tradition, all of which influence how power and responsibilities are exercised, decisions are taken, and partners are included. Furthermore, an understanding of the participants’ way of life is important as a basis for aligning project goals and actor needs, as well as appropriate incentives. We observed that some actors regarded project incentives as a source of income because of
their poor socioeconomic status, as has been documented elsewhere [3]. Incentives must therefore be well articulated to all actors, including the length of the project, to manage expectations, which, if unfulfilled, might jeopardise trust and constrain future relationships.

Fourth, developing shared leadership and responsibility cannot be overemphasised. Transdisciplinary research is premised on the notion that the participation of different partners ensures the sustainability of TD projects beyond the lifespan of the projects. It is important that societal actors are afforded the opportunity to lead several processes and activities of the project: for example, allowing partners to lead data collection and participate in data analysis, which improves their understanding of the importance of research. Lessons from both projects suggest that allowing local community representatives to facilitate workshops in their own language levels the playing field, thereby allowing for the freer participation of community members. LIRA project 2 benefited from this approach, while the LIRA project 1 team has critically reflected on voices that were missing from TD processes in Durban (see Kareem et al. [63]). Although supporting nonacademic partners to facilitate TD activities requires extensive training and employment, the benefits of developing a sense of ownership for project interventions to support impacts beyond the project’s lifespan and scaling to other members of the community far outweigh the costs.

4. Concluding Remarks

In conclusion, undertaking TD research in African cities is not an easy task. Based on our experiences, it is a journey filled with fulfilling experiences, surprises, and setbacks. Drawing on diverse experiences allows for lessons to be gleaned, including identification of common challenges, which can inform TD research in the future. An important finding from this study is that projects need to be designed and implemented collaboratively, from problem formulation to problem solving. Meaningful engagements that value different perspectives build trust and alliances between stakeholders. The outcomes space framework (OSF) provided a useful lens to reflect on transdisciplinarity in an African urban setting, but we suggest using this guiding framework (or another valuable change theory) from the beginning to define project objectives in the realms of changes in the situation, knowledge stocks and flows, and mutual learning. More importantly, the application of such a framework allows TD researchers to reflect on assumptions and iterate as needed. Based on lessons from projects implemented within the LIRA2030 programme, transformative and mutual learning should be a central focus in TD project design, as this supports the coproduction of socially relevant knowledge to address sustainability challenges. It is important to recognise that power dynamics will always be prevalent, including in African urban contexts: dedicated efforts should be targeted at creating a sense of equity among stakeholders. Researchers wield power that can change the direction and outcome of research and should continuously reflect on their positionality in facilitating TD research. The diverse experiences presented in this study indicate that partnerships and relationships, clearly defined leadership roles and responsibilities, design flexibility, social inclusion, and adequate time and financial resources are crucial ingredients for successful TD projects in African urban settings.

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