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Pathways, contextual and cross-scale dynamics of science-policy-society interactions in transdisciplinary research in African cities

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ABSTRACT

The United Nations' Sustainable Development Goals (SDGs) are inherently complex. This paper contributes to the literature on co-production of knowledge at the interface of science, policy, and society in integrated, transdisciplinary research (TDR) projects. By analysing five projects of the Leading Integrated Research for Agenda 2030 in Africa (LIRA) implemented in nine African cities, the paper identifies the pathways for science-policy-society interactions (SPSI) within the TDR projects, the cross-scale and contextual dynamics influencing the interactions as well as the challenges of foregrounding the interactions. We identified four SPSI pathways: i) TDR processes, ii) explicitly conceptualising and communicating research projects in relation to mandates and policies, iii) the global sustainability agenda, and iv) relationships and networks. We argued that these pathways can be construed as important windows for foregrounding SPSI in TDR projects. Cross-scale dynamics such as the spatial scale of interactions, actors' roles, and purposes of engagement were critical determinants of the intensity and frequency of the interactions between the project actors. The analysis suggests that being context-sensitive is key to foregrounding SPSI in TDR projects. Conceptual threshold crossing, resource intensity, power differentials, discontinuity, as well as a history of academic and practice silos present formidable challenges to SPSI in TDR projects. These challenges can be addressed through the identified pathways, adequate capability development; incentivising academics and practitioners engaged in co-production of knowledge; stimulating co-production through adequate resources; building redundancies within the project teams, ideas, and processes, and paying attention to the politics of co-production of knowledge.

1. Introduction

The UN Sustainable Development Goals (SDGs) are inherently complex, as are their interactions (Nilsson et al., 2018). Selomane et al. (2019) argued that although the goals of the Global Agenda 2030 are desirable, the envisaged processes for achieving them are far too simplistic and linear and do not reflect the inherent complexities of the goals. Contrary to the silo approach to problem-solving, strengthening science-policy-society interaction (SPSI) has been conceptualised as a way of navigating the complexity of the sustainability challenges, and accelerating the achievements of the SDGs (Saviano et al., 2019). Each sphere of science, policy, and society plays a critical role in achieving the SDGs. The interaction between science, policy and society in knowledge co-production is critical because it provides opportunity to draw on both academic and practice-based knowledge to effect solutions to complex sustainability challenges. To realise the SDGs, sustainability science conceptualises and emphasises co-production of knowledge at the science, policy, society interface, drawing on multiple knowledge systems, perspectives, and experiences (Clark and Dickson, 2003). The UN identifies five drivers of transformational change that underlie the

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localisation of the SDGs: sensitising, engaging local actors, participatory planning, service delivery, and partnerships. Co-production, which includes SPSI, is sensitive to context, demonstrating the imperatives to translate the global vision of the SDGs into local aspirations.

Scientific training and research in Africa, as in the rest of the world, have been based on disciplines. These disciplines, by forming the basic institutional and cognitive units in academia, define scientific research practices and agendas. The disciplines define scales and depth of internal communications as scientists share basic assumptions and meanings, relate to each other, and establish disciplinary standards (Hadorn et al., 2008). These epistemological structures preserve disciplinary identities, yet the complexity of societal challenges defy disciplinary solutions, boundaries, and imagination.

Interdisciplinary research aims at advancing fundamental understanding or solving problems whose solutions are beyond the scope of a single discipline or area of research practice (Rudall, 1998). Nonetheless, interdisciplinary research is critiqued to downplay co-production of knowledge that involves societal actors, despite the growing recognition that diverse knowledge systems and perspectives are needed to address sustainability challenges. Addressing sustainability challenges, which are themselves wicked and complex, requires disciplinary boundary-crossing, engaging societal actors, and drawing on diverse perspectives to effect solutions (Pohl and Hadorn, 2008a; Reed and Abernethy, 2018; Simon et al., 2018).

The practice of transdisciplinary research (TDR) has been postulated as solution-driven, sensitive to context, and able to draw on diverse knowledge systems, to effect solutions to complex sustainability challenges (Lang et al., 2012; Hansson and Polk, 2018). The TDR emphasises cross-boundary interactions between academic and practice-based actors. Therefore, where interactions across the spheres of science, policy, and society are desired, the TDR is more suitable.

The LIRA programme supports several integrative TDR projects in African cities aimed at contributing to the achievement of the SDGs. In this paper, we interrogate how five of these projects demonstrate SPSI. Specifically, the paper seeks to i) identify pathways for SPSI within the five LIRA-funded TDR projects, ii) reflect on the cross-scale and contextual dynamics influencing the interactions, and iii) reflect on the challenges in foregrounding SPSI in the TDR projects. The paper further explores the influences of the supra-systemic context (Saviano et al., 2019) on the SPSI within the five LIRA projects. The supra-systemic context as used in this paper refers to contextual factors external to the projects which may influence the ways in which different actors interact within the projects. While SPSI has been interrogated elsewhere, literature has not demonstrated strong evidence from the Global South, particularly with regard to the achievement of the SDGs. The triple helix model (Saviano et al., 2019), which emphasises the interaction between the state, academy, and industry, and the 'one world or two' typologies (Sundqvist et al., 2018) are largely silent on the pathways for SPSI, the role of scale and context, as well as challenges in foregrounding SPSI in TDR projects in diverse contexts. In addition to filling these gaps, this paper advances our understanding of the complexity of SPSI in TDR projects as contributions from the Global South.

2. Methods

2.1. Programme summary

The LIRA programme aims to address complex sustainability challenges in African cities and seeks to generate solution-oriented knowledge through integrated TDR projects in African cities Five LIRA projects are included in this study. A summary of the projects is provided in Table 1.

Table 1
Summary of projects analysed in this study.

No.	Project title and (short name)	Project objective and a short description	City and country of implementation	Project sustainability agenda	Project members contributing to this research
1	Enhancing urban river and wetland health (Urban river health)	The project explores ways to improve and restore the integrity of urban rivers (Wupa, Gwagwalada, and Bwari Rivers in Nigeria; Swartkops River in South Africa) by improving water quality, reducing pollution, and improving urban river governance.	Abuja Metro, Nigeria; Nelson Mandela Bay Metro, South Africa.	Urban river water quality, governance and ecosystem health and services: SDGs 6 and 11.	Principal Investigator and Co-principal Investigator
2	Reducing diarrhoea burden under climate change in urban contexts: an integrated approach for sustainability in West African, medium-sized cities (Climate change and diarrhoea)	The project investigates the impact of climate change on diarrhoeal diseases in urban areas, using a transdisciplinary EcoHealth approach. The project facilitates stakeholder participation in the development of new information, strategies, and action for diarrhoeal diseases.	Mbour, Senegal; Korhogo, Côte d'Ivoire.	The nexus between climate change and diarrhoeal diseases: SDGs 3, 6, 11, and 13.	Principal Investigator
3	Household energy use practices and potential interventions for sustainable consumption (Household energy efficiency)	The project uses an action-research approach to investigate household energy consumption practices, with a view to co-designing and implementing, with stakeholders, ways to improve energy efficiency at the household level.	Makhanda (Grahamstown) South Africa; Kumasi, Ghana.	Energy consumption and practices at the household levels – SDGs 7 and 11	Co-principal Investigator
4	Enhancing the sustainability and resilience of African cities through a Water-Energy-Food nexus approach (WEF)	The project uses the Water-Energy-Food (WEF) nexus approach to explore the status and governance of water, energy, and food resources for enhanced resilience of African cities.	Accra, Ghana; and Kampala, Uganda.	Explore the nexus approach to gain access to WEF resources at the city level; SDGs 2, 6, and 7.	project team member
5	Inclusive metabolism: Using the co-produced theory of informal, decentralised urban infrastructures to transform the delivery of urban food, water, and energy services in Ghana and South Africa (Informality and food systems).	The project shed light on how informal food system services in Africa can contribute to food and nutrition security through a strengthened governance system. It has three inter-related aspects: informality; school feeding/urban agriculture; food waste/circular economy.	Accra, Ghana; and Cape Town, South Africa	Role of informality in food and nutrition security: SDGs 2 and 11.	Principal Investigator

2.2. Data collection

We synthesised data from the projects using insights from realist synthesis (RS) (Pawson et al., 2004). We used the RS to develop the data collection template (Table 2) because it is suitable for thinking about, analysing, and synthesising complex, heterogeneous data (Nilsson et al., 2016). Realist synthesis is also amenable to complex interventions, such as those pursued in the five projects, because of its focus on explaining the interactions between mechanisms, context, and outcomes, that is, what works, why, and how? (Pawson et al., 2004; Nilsson et al., 2016). By drawing insights from the RS methodology, we could explore how SPSI played out, the 'why' and 'how' of such interactions, as well as the contextual circumstances influencing the interactions. Relying on insights from RS, we developed a data collection template that has three key dimensions: pathways, scale, and context of SPSI within the projects. This template would enable us to reflect on the causal complexity, cross-scale patterns, successes, and challenges of SPSI within the projects as complex, social interventions (Pawson et al., 2004).

Each investigator was given the data collection template to complete. To avoid the risk of under- and over-reporting, the completed data template for each project was collectively interrogated by the team in a virtual workshop-like setting. This was done to: i) validate the data through an iterative process, ii) promote a shared understanding of the projects, iii) eliminate reporting without adequate empirical evidence.

Table 2
Data collection template applied to the five projects.

Science-policy-society interaction	
Dimensions of the SPSI	Illustrative questions
Pathways	What were the main SPSI pathways in the project? What were the processes and types of stakeholder engagements? Describe the key mechanisms for the interactions. Did the engagement process build on an existing relationship? How did the engagement processes influence the outputs and outcomes of the research project? What were the main obstacles/constraints as well as opportunities for engagement in the project? Indicate unexpected eventualities.
Scale (spatial, jurisdictional, institutional, and temporal) (Cash et al., 2006)	What were the spatial scales of the SPSI in the project? What was the nature of the scaler interaction (e.g., linear, cross-scale)? How does the scale influence the depth of the interaction? What were the scale-related opportunities and constraints to the interactions? How does temporality influence the interaction?
Context	What were the main contextual realities that drive or impede the interactions? Describe the context of the interactions (e.g., political, historical, ecological, social, economic).
Supra-systemic context	
Motivation	How do the main values and norms for the science, policy, and society actors influence the interactions? What were the main motivations for interactions for each actor grouping?
Opportunity	What was the situational condition for the actor constellation that promotes the interactions?
Ability	What were the cognitive affinities of the actor groupings to the problem the project was addressing? How did the knowledge base of the actors influence the interaction?

To explore the influences of the supra-systemic context (Saviano et al., 2019) on the SPSI within the five projects, we developed a second data collection template (Table 2) based on the Steg and Vlek (2008) motivation-opportunity-ability (MOA) model and the Value-Belief-Norm model developed by Stern (2000). The MOA model focuses on opportunity, motivation, and ability at both the organisational and individual levels. The intention was to collect data that permit analysis of how the organisation and individual's context, as well as beliefs, values, and norms, influence the 'why' and 'how' of the actors' interactions in the respective projects. Motivation is regarded as the beliefs, attitudes, intentions, and social norms; opportunity is the situational condition that enables the individual to perform. Ability is construed as habits and task knowledge. We draw on the MOA model because we believe it permits an analysis of the supra-systemic context.

Instead of the original university-government-industry helix (Etzkowitz and Leydesdorff, 1995; Cai, 2014), we conceptualised a science-policy-society helix (the shaded block of Fig. 1). Society here is conceptualised as any component of the helix which could not be categorised as science/university or policy/government, including government agencies/entities across administrative scales. In the original helix, the state constituted both the government/policy and the society. In our working helix (the shaded block), the government/policy is separated from society. Society includes local communities, civil society organisations and non-governmental organisations. Science is defined as academia, as in the original helix. Policy is defined as government policy or government agencies and actors.

2.3. Data analysis

We populated the data collection template and analysed the data using thematic analysis (Braun and Clarke, 2006) to identify patterns and themes. Thematic analysis enables coding of patterns and establishing a framework for presenting the hidden meaning within data. The framework used followed the six steps described by Braun and Clarke (2006). The data analyses were initially carried out independently by members of the team after which, the identified themes were checked against each other and merged to ensure saturation and validity. The themes were then re-validated through group meetings and reflections.

3. Results

3.1. 3.1 Pathways for SPSI

3.1.1. Pathway 1: TDR processes

All five projects were intentionally designed as TDR projects. We found that being intentionally transdisciplinary provided multiple windows for SPSI. In all the projects, the research problems were co-identified between the academic, policy, and societal actors. In some of the projects (e.g., the project on household energy efficiency), the desired change and interventions were also co-identified. This co-identification process provided the impetus for research co-ownership and stimulated a deep interest and desire on the part of the actors to engage as the research projects were generally perceived as addressing relevant issues. The solution and development orientation of the projects provided multiple avenues for foregrounding SPSI in the projects. We found that in all the projects, co-implementation enhanced co-learning, co-monitoring, adaptation, as well as resource-, data-, and information-sharing between the actors.

3.1.2. Pathway 2: explicitly conceptualise and communicate research projects in relation to mandates and policies

In conceptualising and communicating the projects, explicit links to critical national policies and strategies should be made. Our reflective analysis revealed that research explicitly linked to official mandates and relevant policies, at either local or national levels, provided a pathway

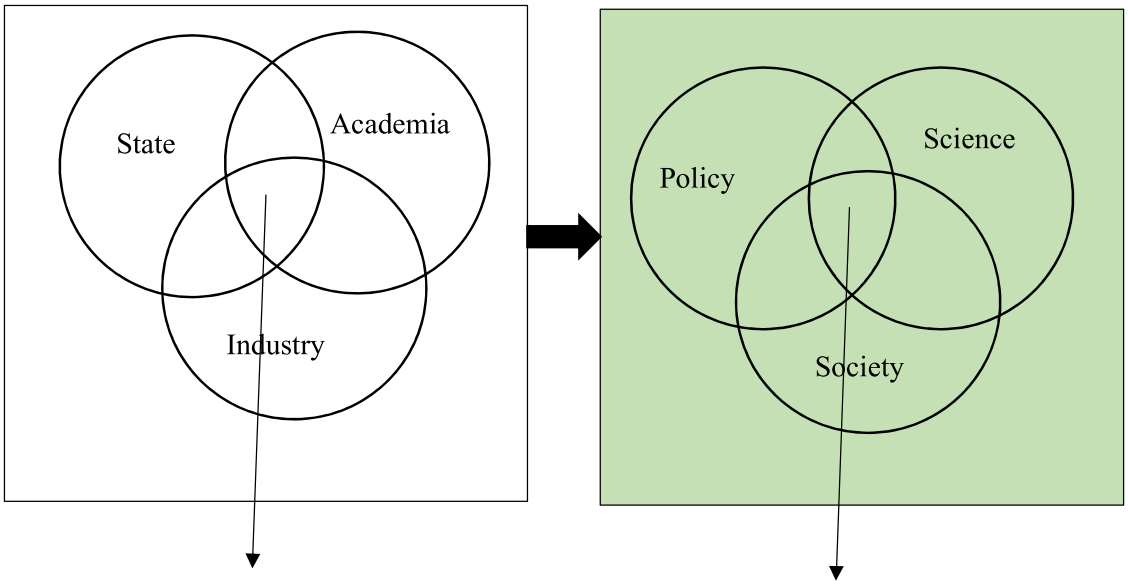

Fig. 1. Conceptualisation of the science-policy-society interaction (Based on Ranga and Etzkowitz, 2013).

for engagement with both policy and societal actors. For example, for the urban river health project, the South African Department of Water and Sanitation (DWS) is legally mandated by the National Water Act (Act No 36 of 1998) (Republic of South Africa, 1998) to protect river resources. The DWS has an ongoing water quality monitoring programme in the Swartkops River. Similarly, the municipality is legally mandated to ensure water quality compliance by regularly monitoring effluent. The core mandate of one of the societal actors, the Zwartkops Nature Conservancy, is to ensure the conservation of the Swartkops River. Positioning and situating the research project within the core mandates and existing programmes of these organisations provided incentives for engagement.

The climate change and diarrhoea project, which focuses on the interaction between climate change and diarrhoea was positioned within the provisions of the Senegalese National Health Development Plan, *Plan National de Développement Sanitaire* (PNDS); the Strategic integrated Reproductive, Maternal, New-born, Infant and Adolescent Health plan (SRMNIA) as well as the climate change policy and National Adaptation Programme of Action (MSAS, 2018). These plans provided impetus for engagement with policy and societal actors. We made similar observations for the other projects: for example, the project on household energy efficiency was firmly situated within the Ghana National Energy Policy (Ministry of Energy, 2010), and the Ghana Action Plan on Sustainable Energy for the global agenda (Energy Commission, 2012). The informality and food system project was built on the National Food Security and Nutrition Plan and City of Cape Town's Resilience Strategy, and the Kumasi Metropolitan Assembly's Strategic Plan 2014–2017.

3.1.3. Pathway 3: global sustainability agenda

Intentionally framing research challenges in terms of the global sustainability agenda provided traction for SPSI. In the case of the analysed projects, many of the policy and societal actors were already very active in localising the SDGs. In the City of Cape Town, where the project on informality and food system was being implemented, the Peninsula Feeding Scheme (an NGO) which had received funding from the National Lottery Commission was active in implementing SDG 2 (zero hunger) among school children. The informality and food system project gained traction with both governmental and non-governmental organisations active in exploring the role of informality in addressing food insecurity in Africa. Similarly, the household energy efficiency project was attractive to both the energy regulators and civil society organisations because it uses SDGs 7 and 11 as entry points to actors who were already active in this domain. Similar observations were made for the other projects. Owing to the way in which global policies influence national policies, pathway 2 provided the opportunity to address local priorities. Unlike pathway 2, pathway 3 allows local actions to be linked to the global agenda and vice versa.

3.1.4. Pathway 4: relationships and networks (formal and informal)

Our analysis revealed that all five projects relied heavily on existing relationships that the team members had developed with either societal or policy actors. The project on urban river health, for example, capitalised on over eight years of an existing relationship with the Nelson Mandela Bay municipality. Similarly, the climate change and diarrhoea project was built on long-standing professional and personal relationships with policy actors in the Ministry of Health in Senegal and the municipalities in Mbour (Senegal) and Korhogo (Côte d'Ivoire). Often, the process of engaging with policy and societal actors in the projects started with an individual in the policy and societal sphere, who became an initial anchor person for the project in their respective organisations. We have termed these people, "critical resource persons". They play important roles in the research projects with regard to SPSI. These roles are diverse and include i) serving as the project entry point in the policy and societal organisations, ii) aiding the institutionalisation of the research projects within their respective organisations, iii) advocating and lobbying institutional support for the projects, iv) raising project profile and awareness within organisations and among colleagues, and v) facilitating the co-creation of knowledge, active data-, and information-sharing.

3.2. Scales of SPSI in the TDR projects

The analysis also revealed that engagement with societal and policy actors took place at multiple scales (Appendix A). The selection of the actors at each scale was determined by the actor's role and the purpose of engagement, which in turn, determined the intensity and frequency of interactions (Fig. 2). The depth of engagement varied between actors per project. For example, the engagement with local communities and municipal authorities in the projects on climate change and diarrhoea, WEF, and informality and food systems were in-depth, involving co-identification of research problems, data sharing, and co-production of knowledge. National actors were occasionally engaged but were kept informed of the projects' progress. In the case of the household energy

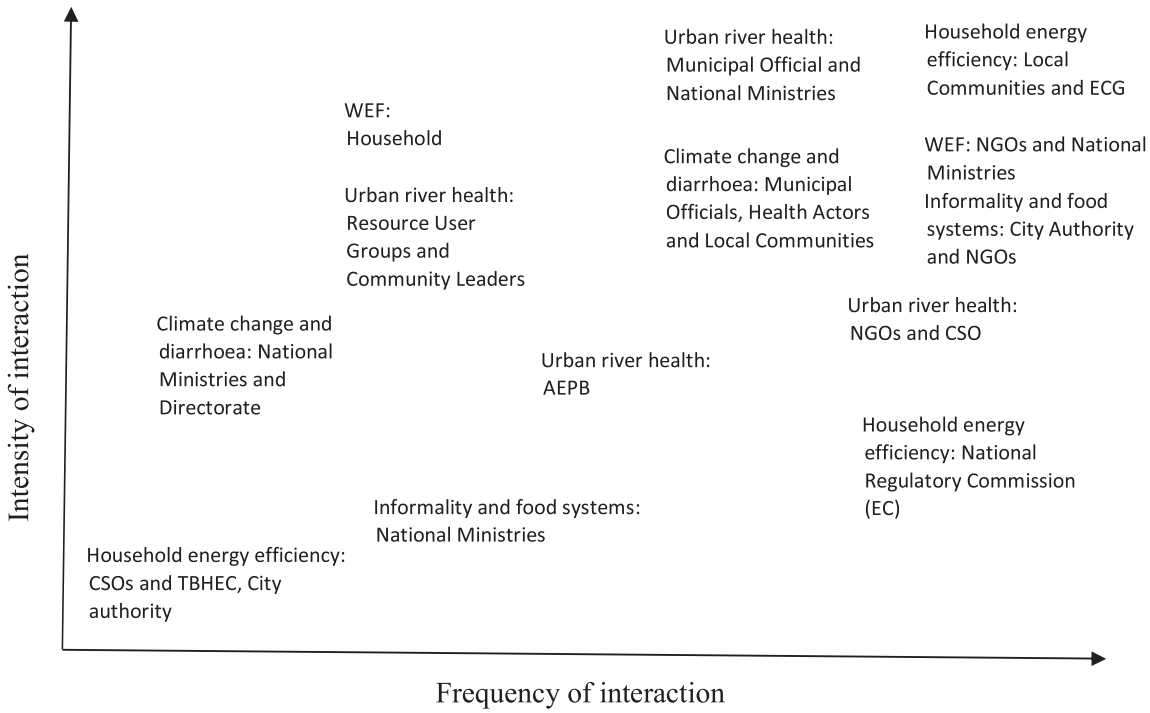

Fig. 2. Intensity (relative time spent per engagement) and frequency of interactions between various actors across the triad of science-policy-society interaction across the five projects.

efficiency project, national, municipal, and local actors were engaged throughout the project lifecycle. For the urban river health project, both municipal and national authorities were engaged in-depth and were involved in both research problem identification and knowledge co-production. In this project, local community user groups were only engaged during specific aspects of the project but were informed of project processes and outcomes. Differential stakeholders' depth of engagement was informed by different aspects of project objectives; for example, when matters of ecosystem services and livelihoods were being addressed all stakeholders, from national to local authorities, including community user groups, were engaged at the same depth. However, when matters relating to the failure of cooperative governance between national and local tiers of governments were being addressed, resource users' groups were engaged only to the extent that their livelihoods had been affected by such failures to strengthen the argument for cooperation between the tiers of government. Our analysis suggests that the criticality of the scale of engagement depends on the societal and policy challenge the project sought to address, and on the actors involved.

Initiating and sustaining long-term relationships with stakeholders was critical for the projects. The analysis suggests that mutual respect for all stakeholders' interests, voices and aspirations, trust, shared understanding of interests and values, were essential for sustaining long-term intensive and frequent engagement. On the other hand, SPSI in research projects can be undermined when the research problem is highly contested, and opposing and antagonistic actors are brought together. As inequalities and inequities are driving forces of contestation, our analysis suggests that paying attention to issues of social justice in project design and actors' consideration is an important way of ensuring the SPSI progresses in a contested space. In the instance of the project on urban river health, the challenge of the contested research problem was dealt with by co-developing ground rules/norms such as equality of rights and voices, respect for all, and foregrounding equity in all project processes and outcomes. These ground rules guided project workshops and informed actors' participation in the project.

In sum, the spatial scale and depth of engagement were primarily determined by i) the nature of the research problem(s), ii) the role(s) of the actor(s), and iii) the purpose(s) of engagement. In instances where the engagement purpose was to better understand community behaviour, long-term, in-depth engagement was necessary, whereas short-term engagement was enough when only access to specific data was needed. Within the projects, some actors were regularly engaged, with a relatively long time spent per engagement. Examples of engagement methods requiring long engagement time were workshops, organised face-to-face meetings, or online meetings.

The methods of engagement were diverse across the projects and were primarily determined by the depth and frequency of engagement. Where in-depth and frequent engagement was necessary, methods such as workshops, face-to-face meetings, the establishment of community of practice (COP) as well as working groups were employed. Where in-depth, but less frequent engagement was required, methods such as narrative enquiry (e.g., project on informality and food systems), key informant interviews and surveys were employed (e.g., projects on urban river health, climate change and diarrhoea, household energy efficiency, WEF, informality and food systems).

Scale has implications for SPSI. Although the scale of engagement depended on the research project, it was relatively easier to engage at a local scale e.g., household energy efficiency project engaging with households. Where governance issues were prevalent, national, and municipal scales (jurisdictional scale) of interaction were pre-eminent. Engagement at the national level comes with bureaucratic challenges.

3.3. Context dynamics of SPSI in TDR projects: exploring the mediating role of the supra-systemic contexts in TDR projects

The contextual realities facilitating or impeding SPSI in the projects were diverse and included biophysical, social, economic, organisational, and policy contexts. These collectively form a supra-systemic context and are analysed using the MOA model.

3.3.1. Motivation

In a detailed dissertation on motivation, Sikula (1971) lists values and needs as internal determinants of motivation. Across the five

projects, societal developmental needs birthed the research projects. At the policy level, the mandate of the various governmental institutions either as duty bearers, policymakers, implementation agencies, or regulators defined their needs and informed their values. Therefore, government institutions for health, food and nutrition, water, energy, urban development, and governance operated to address developmental issues that focused on the needs of the society. The needs of the academic actors were research and development, and accredited outputs such as publication, reputation, and career progression. The societal actors were driven mainly by the pressing challenges confronting their communities.

3.3.2. Opportunity

Opportunity denotes situational conditions which enable the individual or an entity to perform. We examined situational conditions within the five projects that promoted the SPSI. These situational conditions ranged from awareness of the global sustainability agenda to local policy, community, and environmental issues, which society and policy actors desired to address. For example, in the household energy efficiency project, residential energy consumption was reported to have risen consistently from 3.2% in 2004–13.7% as of 2010 (Energy Commission, 2012; 2017) with resultant power crises. Residential consumption of electricity increased from 1996 GWh in 2007–3060 GWh in 2013 (Adom, 2011). This excessive energy consumption at the household level was largely due to inefficient use (Stephenson et al., 2010; Van Den Brom et al., 2017). The Energy regulator's effort to address the growing household energy use inefficiencies in Ghana provided a fertile contextual impetus for policy engagement in the project. The National Energy Efficiency Action Plan of Ghana (Ministry of Power, 2015), Ghana Appliance Energy Efficiency Strategy (Edjekumhene, 2017), and Efficiency Standards and Labelling provided further policy context for engagement. The potential savings accruing from efficient energy use on the part of the consumers (households) was attractive to the societal actors.

The WEF project implemented in both Accra and Kampala was driven by social, economic, and biophysical, as well as policy contextual realities. Both cities faced a water security stress which required an orientation towards environmental resilience. In Accra, for example, water demand already exceeds supply (Van-Rooijen et al., 2008) and electricity crises have been frequent (Kumi, 2017). Meanwhile, the demand for these resources will increase significantly with time, owing to factors such as increased population (FAO, 2014), which may lead to an increase in competition and result in unpredictable impacts on livelihoods and the environment. The crisis compelled policy actors to be more amenable to research engagement.

The project on informality and food systems in African cities was mainly facilitated by social imperatives to secure food and nutrition security for school children. Policy actors' challenges in addressing the concern of increasing hunger in public schools provided incentives for their engagement in the project. On the other hand, various societal actors, for example, small-scale farmers, food vendors, and NGOs in the food sectors engaged in the project for diverse contextual factors. For the vendors, the project provided the opportunity on how food waste can be reduced, and how the principles of circular economy can be adopted.

In the urban river health project, the high levels of pollution in the Swartkops River (South Africa) and Wupa, Gwagwalada Rivers (Nigeria), loss of biodiversity, and compromised ecosystem services have been reported in the scientific literature (Ojutiku et al., 2014; Nel et al., 2015; Odume et al., 2015; Okafor and Olawale, 2020). Community awareness of the pollution in the Swartkops River in South Africa, and the solid waste management problem on the catchment of the Gwagwalada River in Nigeria facilitated engagement with societal actors, such as NGOs and community-based organisations (CBOs).

3.3.3. Ability

Ability has been defined as habit and task knowledge (Steg and Vlek, 2008). The policy actors of the WEF project exhibited in-depth knowledge of policies and legislation governing their respective areas of operations, but were less familiar with the nexus approach to resource governance. Consequently, the interactions between the WEF actors were limited. An external stimulus (in this case the research project) was necessary to catalyse interaction. Policy actors in the urban river health project in South Africa demonstrated competency in river health monitoring techniques and tools; by contrast, their counterparts in Nigeria exhibited a gap in their technical capacities, particularly in river health assessment. Societal actors in the urban river health project expressed local catchment knowledge, which shaped the project.

Based on Erving Goffman's Social interaction and micro-sociology (Jacobsen, 2017), the projects were observed for exchange, competition, cooperation, conflict, and coercion between the triads in operation. Where similar task habits were identified, interactions were identified as intense and positive. For example, in the household energy the legislation required cooperation between the government (Ministry of Energy) and the government utility agency, and the local governments (local level policy actors); however, power relations shifted, leading to coercion.

3.4. Challenges in foregrounding SPSI in the projects

In the projects we analysed, we identified five principal challenges for SPSI. These challenges are presented and discussed below.

3.4.1. Challenge 1: conceptual threshold crossing

Foregrounding SPSI implies active engagement of diverse actors, often with different discursive language and epistemic backgrounds. Translating academic discourse into accessible everyday language can be challenging and may prove a barrier for co-production. In the same vein, policy and societal actors use discourse unfamiliar to academic actors. In the projects, achieving joint (science, policy, and societal actors) conceptual threshold crossing in terms of intellectual, ontological, and cognitive transformation was perhaps one of the greatest challenges to foregrounding SPSI. Since the projects were not just about understanding the problems or raising awareness, but about true co-production of knowledge and co-ownership of the resulting outcomes, joint conceptual threshold crossing was inevitable, yet proved challenging to achieve. We identified two reasons for this. First, the diversity of the actors' epistemic backgrounds in the projects. In the urban river health project, for example, the project team came from multiple academic disciplines, policy contexts, and societal domains – each with a discursive language which needed to be transcended to achieve conceptual threshold crossing. Second is the varied level of past experiences in integrative research projects among actors. The WEF project, for example, saw some actors actively involved in an integrative research project for the first time, and in most cases, this was their first exposure to academic discourse. Even though most of the actors had experience of collaborating in similar projects, this was not enough to accelerate joint conceptual threshold crossing.

3.4.2. Challenge 2: resource-use intensity

Inadequate availability of resources such as time, human resources, funds, can pose a significant challenge to TDR. A major challenge experienced in the projects was the resource-intensive nature of knowledge co-production at the interface of science, policy, and society. Although the projects were adequately funded by the LIRA 2030 Africa programme, we found that, without such financial support, it would have been impossible to realise the extent of interactions achieved in the projects. The frequency and intensity of engagement between the actors were costly in terms of scheduling of meetings, venues for such meetings, as well as time. With regard to time, in nearly all the projects, it was often difficult to schedule meetings that suited all critical actors. We also found the implementation process of the projects was slow compared to our experience of implementing disciplinary projects. In all the projects, the actors were diverse; so were their needs, interests, and aspirations.

Trying to find common ground, which often shifted as the projects progressed, was a major challenge that constantly impeded the pace of project implementation.

3.4.3. Challenge 3: power differentials, values, and ethics

The diversity of the actors involved in the projects also implies inherent power differentials. The academic actors, for example, were epistemically powerful in the academic discourse of the projects, whereas the policy actors were influential in determining whether the project outcomes get to be used in the policy arena or not. The influence of power and diverse values became even stronger in projects implemented in contested spaces. For example, in the urban river health project, the project topic was socially contested to the extent that, even though the actors agreed on improving the water quality, the attribution of river pollution to certain stakeholders was a major source of contestation. When inherent power differentials are embedded in a project through actors' diversity, the ethical challenge is brought to the fore, calling for tactful balancing of multi-actors' interests, values, and power dynamics. This requirement was particularly important for all the projects to ensure that the voices of the less powerful actors were not only captured, but that they were reflected in the project implementation and outcomes.

3.4.4. Challenge 4: walking the last mile

We have used the analogy 'walking the last mile' to illustrate the importance of ensuring that discontinuity and participation fatigue are adequately managed to ensure that the interests of critical actors in projects are sustained from co-identification of research problems through co-production and dissemination. Discontinuity of people and ideas, as well as participation fatigue, have been identified as key challenges in TDR projects (Rogers et al., 2013; Palmer et al., 2015; Schneider and Buser, 2018). Our experiences of implementing the projects suggest that discontinuity and participation fatigue are inevitable. Building enough redundancy within the projects across the science, policy, and society domains was an important strategy for coping with and adapting to discontinuity. By redundancy, we mean embedding in the projects multiple actors who could play the same or similar roles, so helping to minimise the negative effects of discontinuity of people or ideas.

3.4.5. Challenge 5: a history of academic and practice silos

In the projects we analysed, it was the first time many of the academic actors had participated intensely in TDR projects and knowledge co-production. One of the challenges experienced about the 'academic silo' was that of integration. The integration challenge manifested as conceptual, practical, and methodological. For example, in the project on climate change and diarrhoea, the academic actors had to wrestle with ways to truly integrate biophysical data on climate change and incidences of diarrhoea with social data on values and perceptions of the key drivers of diarrhoea. Multi-sectoral collaboration was non-existent. The academic actors in the WEF project also faced problems in implementing the nexus methodology (consisting of natural and social science methods, and qualitative and quantitative methods). Our collective experiences in implementing the projects indicate that the policy actors had a history of working in silos, and multi-sectoral collaboration was either completely lacking or poorly developed. In the case of the household energy efficiency project, a section of the policy actors (the local government) were passive participants because, despite legislative requirements to cooperate with the national utility agency, in practice, there were barriers to cooperation. Similarly, within the urban river health project in the South African case study, several municipal divisions/units including the wastewater division, solid waste division, stormwater division, and environmental health department had bearing on the Swartkops River systems. Even though their operations are linked and connected, the empirical evidence during project implementation suggested little collaboration among the divisions.

4. Discussion

This paper sought to identify pathways for SPSI in TDR projects and the contextual dynamics influencing the interactions, as well as the challenges of foregrounding the interactions at the interface of science, policy, and society. New modes of knowledge production such as post-normal science (Funtowicz and Ravetz, 1994; Wesselink and Hoppe, 2011), engaged participatory research (McElfish et al., 2018), action research (O'Reilly-De Brún et al., 2016) and TDR have emerged as potential solutions to addressing wicked sustainability problems (Cash et al., 2003; Lawrence, 2015; Wolff et al., 2019).

What is common to these new forms of knowledge production is the involvement of non-academic actors in the research process. In the present study, we shed light on the pathways for SPSI in integrated research projects aimed at addressing sustainability challenges. We found that TDR processes, such as careful co-identification of research problems, co-design of the research projects as well as co-implementation, and continuous learning and adaptation, provided strong motivation for interactions between science, policy, and societal actors, thus foregrounding salience, legitimacy, and credibility (Hansson and Polk, 2018). We conclude that TDR processes are important levers for addressing academic and practice silos which have been identified in our analysis as important impediments to the co-production of knowledge at the interface of science, policy, and society.

Contexts can provide windows of opportunity for engaging policy and societal actors in research projects. In analysing and reflecting on a conservation project in Columbia, Nostrom et al. (2020) argue that the political window provided by Columbia's Nationally Determined Carbon Contribution (NDC) to climate change and the REDPARQUES Declaration were instrumental in the success of an integrated research project which brought together policy, academic and societal actors. Our analysis revealed that policy actors often operate within a defined political context and are driven by official mandates and policies (Roux et al., 2017; Thompson et al., 2017; Ghodsvali et al., 2019). For example, we found that municipal officials across the project cities often refer to their mandates and policies as a compass that guides their daily action. The willingness of policy actors to engage and contribute to the research projects was enhanced when the projects were seen to be in alignment with their mandates and policies. Our results suggest that exploitation of the policy and political contexts can be an effective pathway for SPSI in research projects. Overall, the relevance of context for co-production has been stressed by multiple authors (e.g., Thoni and Livingston, 2021; Nostrom et al., 2020).

As countries race to localise and implement the SDGs, policy and societal actors such as NGOs and CSOs are increasingly recognising the need to draw on and engage diverse actors and knowledge systems. Regarding the sustainability agenda as a pathway, Morgan (2014) identified issue identification and analysis, consultation, and coordination, and generating evidence in support of decision making as examples of the purposes for which stakeholders engage science. All of these were evident in the five projects, suggesting that the global sustainability agenda offers a credible window for SPSI. In all the projects, the complexity inherent in localising the sustainability agenda engendered varied degrees of stakeholder participation, ranging from informing, consulting, and placating to partnership and transformative interactions, as well as engaged knowledge co-production (Schneider and Buser, 2018).

Social networks and relationships have emerged as fundamental to sustainable co-management and governance of natural resources (Garcia-Amado et al., 2012). They are influential in terms of information flow, and in shaping perceptions, building trust, resolving conflict, sharing benefits, and agreeing on collective actions, as well as impacting on environmental outcomes (Ghodsvali et al., 2019). In this study, we found social networks and relationships were important pathways for SPSI in the projects. Policy and societal actors with whom academic project leaders had developed relationships based on trust and previous

experience played critical roles in the conceptualisation phases of the projects, and in anchoring the projects within their respective organisations, communities, or social groups. These social networks and relationships accelerate and deepen engagement with policy and societal actors.

The idea that SPSI is linear has been criticised (Morgan, 2014), and our analysis exemplified the complexity of the interactions through multi-scalar and contextual dynamics embedded in the projects. Across all the projects, the interactions were multi-dimensional, non-linear, and were influenced by the agenda, actor's role, policy, economic, social, and ecological contexts, as well as the perceived role of science in the policy and societal domains. For example, in all the projects, policy and societal actors were part of the research conceptualisation through to co-implementation, but these roles for policy and societal actors were not consistent between and within projects. The diversity of actors' roles and scale of interaction influenced the frequency and intensity of the interactions. For example, interaction intensity was high when the actors were perceived to be critical to influencing practices that impact the sustainability challenge at the appropriate scale of project implementation. Overall, our results support the view of the SPSI as 'messy', webbed, non-linear and complex, requiring attention to power dynamics, conflict resolution, reciprocity, benefit-sharing, and due acknowledgement (Wesselink and Hoppe, 2011).

In foregrounding SPSI through co-production, we encountered several challenges: i) conceptual threshold crossing, ii) resource intensity, iii) power differentials, values, and ethics, iv) walking the last mile (discontinuity), and v) a history of academic and practice silos. When not adequately addressed, each of these challenges presents formidable barriers to true co-production. For example, paying attention to power and politics has recently been identified as critical to co-production achieving its intended goal of societal and environmental governance transformation (Turnhout et al., 2020). Our projects bring to the fore the ethical dilemma that confronts scientists involved in co-production regarding how to balance interests, values, and power asymmetry inherent in co-production spaces. We suggest that projects mainstreaming SPSI identify sources of inherent power, the context of the exercise of power, and should make explicit the often-implicit assumptions, values, and expectations held by the actors regarding participation in a project. Further, scientists involved in co-production should also consider both practical and conceptual barriers that hinder true co-production. The identified challenges can be addressed through the identified pathways as well as reflection on the context and scale of project implementation. For example, we found that the TDR processes provided windows for addressing both academic and practice silos since all-important actors were involved from project inception through implementation. Challenges related to conceptual threshold crossing can be mitigated in part through a participatory, engaged research process, informed by reflexive learning and openness (Sendall et al., 2018).

Even though SPSI, through co-production, has become a booming field of research (Edelenbos et al., 2011; Pohl and Wuelser, 2019), our experience suggests that the process is not only resource-intensive but could also suffer from the inertia of a history of both academic and practice silos. How does one shift through a single project history of academic and practice silos, and accept that co-production, which is both time-consuming, resource-intensive, and intellectually demanding is the way to go? This question not only raises the imperative for making resources available for co-production, but it also raises the importance of capability development and incentivising practitioners and academics involved in co-production for SPSI. To mainstream SPSI through co-production we suggest i) addressing academic and practice silos through adequate capability development and incentivising academics and practitioners; ii) stimulating co-production through adequate resources, for example, project funding and mentorship, and iii) addressing discontinuity of both ideas and people through redundancies within the project teams and processes.

Drawing on the MOA model (Steg and Vlek, 2008), we defined the supra-systemic context as comprising motivation, opportunity, and ability. Our analysis intended to surface the 'why' and 'how' of the actors' interactions in the respective projects, by looking more widely into the context of actors beyond that provided by the projects. Our results suggest that actors' individual and organisational values and norms were vital in influencing the intensity and depth at which they participated in the projects. For example, where actors' organisational values support research engagement, actors from such organisations were more open to deepening the interactions.

5. Conclusion

In this paper, we analysed five integrated projects implemented in nine African cities to identify pathways for SPSI in TDR projects, the cross-scale and contextual dynamics influencing the interactions, the challenges of foregrounding the interactions as contributions to the academic discourse on co-production, as well as the literature on SPSI. We identified four pathways: i) TDR processes, ii) explicitly conceptualise and communicate research projects in relation to mandates and policies, ii) the global sustainability agenda, and iv) relationships and networks. These pathways can be construed as important windows for foregrounding SPSI in integrated research projects. Science-policy-society interaction via co-production is complex. Cross-scale dynamics such as the spatial and jurisdictional scale of interactions, actors' roles, and purposes of engagement were critical determinants of the intensity and frequency of SPSI, as well as the methods and modes of engagement between the actors. Our analysis suggests that projects aiming to foreground SPSI must be sensitive to the ecological, social, economic, and policy contexts. We identified conceptual threshold crossing, resource intensity, power differentials, values and ethics, walking the last mile, and a history of academic and practice silos as formidable challenges of SPSI. These challenges can be addressed by developing adequate capability, incentivising academics and practitioners, stimulating co-production through adequate resources, building redundancies within the project teams and processes, and by paying attention to the politics of co-production.

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CRediT authorship contribution statement

All authors contributed to all aspects of the paper: conceptualisation, data curation, data analysis, funding acquisition, methodology, writing, reviewing, etc.

Declaration of Competing Interest

The authors declare no conflict of interest regarding this publication.

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Appendix A. Multi-spatial scales of actors' engagement across the five projects

Project	Spatial scale of engagement, actors, and the primary aim of the engagement			
	City level (local)	Regional/provincial/state/district	National	International
Urban river health	Municipal Officials – co-identification of the research problem and knowledge co-production. Resource user groups – perceptions of pollution effects on ecosystem services. Local community leaders – historical perspective. NGOs and CSOs – pollution effect on ecosystem services and historical perspectives.	Abuja Environmental Protection Board (AEPB) – knowledge co-production.	National Ministries, Department, and Agencies – project co-design and co-implementation.	
Climate change and diarrhoea	Municipal and health authorities – co-identification of challenges and co-implementation. Local community leaders – co-identification of challenges.	Korhogo Head of Regional Health Department – involved in co-production workshop. Mbour health district and municipal actors involved in co-production workshop and data collection.	National Ministries and Directorate – policy interrogation.	
Household energy efficiency	Households – co-generation of knowledge on energy consumption, co-design of interventions, co-monitoring of interventions. City authorities – co-production of knowledge. CSO – co-production of knowledge. The Brew Hammond Energy Centre (THBEC) – co-production of knowledge.	Electricity Company of Ghana (ECG) – involved in co-production, co-monitoring of interventions. Metropolitan, Municipal, and District Assemblies (MMDAs) – co-production of knowledge	Energy Commission (EC) of Ghana – interrogate the energy regulatory landscape, co-production of knowledge.	
WEF	Households – generate local knowledge on WEF. NGOs and CSOs – co-production of knowledge.	Kampala Capital City Authority – involved in co-production workshop.	National agencies and ministries – involved in co-production workshop.	International Water Management Institute (IWMI) – involved in co-production workshop. West African Science Service Centre in Climate Change and Adapted Land Use (WASCAL) – involved in co-production workshop.
Informality and food systems	NGOs – Advocacy, co-design, and implementation of a school garden. Food vendors – a survey of vegetable vendors on livelihood and market infrastructure. Accra and Cape Town city authorities – co-identification of research problems and policy interrogation.	Oforikrom and Ejisu Municipal Assemblies – knowledge sharing and co-production with Market Coordinating Councils		City officials from the Philippines, Botswana, United Kingdom, USA, Italy, Nigeria, Belgium, Côte Ivoire, Cameroon –online co-production workshop.

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