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ARTICLE

Keeping the doors open: experimenting science–policy–practice interfaces in Africa for sustainable urban development

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Abstract
Academics and policy-makers are increasingly being challenged to acknowledge that their knowledge is necessary but insufficient in addressing the complex challenges associated with global urbanization. But few studies offer a coherent framing of how actors from academia, policy and local communities can interface and build synergies for resolving urban sustainability challenges. This paper presents three parameters along which science–policy–practice interfaces for urban sustainability can be understood. The three parameters are: (1) co-framing research agendas; (2) co-designing methodologies; and (3) co-experimentation of scalable solutions. Co-framing research agendas speaks to the process of jointly developing research problems and questions from on a particular or interrelated set of urban sustainability challenges. Co-designing methodologies centers on the spectrum of approaches and methods for generating and sharing knowledge that is scientifically credible, relevant to policy and socially valuable. Co-experimentation refers to testing or taking to scale locally-embedded solutions that can resonate with systemic change at wider scales. To illustrate the contextual meanings and dynamics of these three parameters, case studies of interfaces amongst academic and non-academic actors are presented from cities of Durban, Stellenbosch and Kampala. The case studies demonstrate that all the parameters mean altering the positionality of local communities and policy-makers, from end-users to co-bearers of knowledge with scientists from academia. None of the case studies indicates that one parameter is a step to another, rather the emphasis is on reflexive modes of collaboration amongst the actors involved to permit the co-production of knowledge.

Keywords Urban sustainability · Co-production · Experimentation · Science · Policy · Practice

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1 Introduction

Whenever a city is grappling with a complex challenge like climate change or protection of green cover from private interests, both science and policy are tempted to borrow approaches or models and planning expertise from the most studied and well planned cities (Watson 2014; Obeng-Odoom 2015). The emergence of varied concepts, such as "smart cities" and "eco-cities", has even made the quest for nuanced urban practices a complex endeavor with unprecedented overlaps in stakeholder interests and a multiplicity of solutions, which are never completely right, but rarely completely wrong. This is particularly true for many African cities, whose local institutional capacity is often seeking to cope with interactions among heterogeneous agents and components across multiple scales. Such agents mainly include neighborhood associations, businesses entities, higher and lower local governments, for-profit intermediaries, intergovernmental organizations and non-profit advocates, whose agendas are growing exponentially on the continent under the banner of sustainability, with a conflation of recipes on how urban development challenges can be resolved. The different ways of engagement, linking and construction of organizational and individual expertise in the field of Africa's urban sustainability, is driven by the fast and uncontrolled urban growth trends on the continent that present several challenges such as housing informality, poor sanitation and inequality (Cilliers et al. 2011; Turok 2016; UNECA 2017).

Seven of the world's ten new anticipated megacities to be added by 2030 are found in Africa (United Nations 2016). These include: Cairo (Egypt), Accra (Ghana), Johannesburg-Pretoria (South Africa), Khartoum (Sudan), Kinshasa-Brazzaville (Democratic Republic of the Congo), Lagos (Nigeria) and Nairobi (Kenya). It is also important to note that cities in Africa are a landscape of multiple ecologies with abundant natural resources that span over coastal, in-land, mountainous and semi-arid cities, which harbor different pathways for confronting urban sustainability challenges at global scale (Lwasa 2014). Therefore African cities offer enormous opportunities for innovation and experimentation of scalable solutions to urban sustainability challenges, through interfaces amongst actors from science, policy and local communities. However, the experimentation of science–policy–practice interfaces in African cities is perhaps one of the most stark knowledge gaps in literature on urban sustainability. This can be attributed to several underlying reasons. The experimentation of science–policy–practice interfaces is often framed as a phenomenon of co-producing knowledge in cities in the global north, and the co-production of knowledge in the global south, particularly in African cities, is often overlooked and not well documented in academic literature, except perhaps some work focusing on Asia (Bai et al. 2010; Lang et al. 2012; Swilling 2014; Van Breda and Swilling 2018). In fact, the dominant framings that speak to the need for science–policy–practice interfaces on urban issues, such as urban tinkering (Elmqvist et al. 2018) and urban experimentation (Evans 2016) or the critique of it, often overlook the lesson that many urban 'solutions' developed in the context of northern cities do not apply well to cities in Africa (Parnell and Robinson 2012). For example, in African cities, high-tech smart technologies that transform waste to energy may be less effective because of the existence of large informal networks of waste pickers who manually extract and add-value to waste materials using technologies developed from local hardware (Buyana and Lwasa 2011). Therefore urban concepts and experiments for science–policy–practice interfaces that are designed for developed world contexts cannot be uncritically replicated and transferred to developing world contexts. Conversely, the available evidence on African cities is largely analysis of case studies, with minimal effort to build conceptual lenses that define the contextual features of science–policy–practice interfaces on the continent. This paper presents three parameters along which science–policy–practice interfaces for urban sustainability can be understood, by drawing on case studies from African cities including Durban, Stellenbosch and Kampala.

2 Materials and methods

The purposive selection of Durban and Stellenbosch in South Africa as well as Kampala city in Uganda, permitted review of documents and interactions with a diverse set of actors across human settlements that represent different spatial settings, population characteristics and urban actors. Two human settlements and one municipality were studied: Enkanini settlement in Stellenbosch; eThekwini Municipality in Durban; and Bwaise III settlement in Kampala city. Established in 2006, Enkanini is located approximately 4 km from the center of Stellenbosch town with over 6000 residents. About 2494 households live in shacks with no formal housing and drainage systems coupled with difficulty for the municipality to justify provision of basic sanitation and energy services, as they do not receive rate payments from residents to cover these costs (Stellenbosch Municipality 2012). The settlement was created when the evicted backyard shack dwellers of the neighboring Kayamandi Township occupied the adjacent land. EThekwini Municipality on the other hand, has more than 400,000 people living in informal settlements and located within KwaZulu-Natal (KZN). This is a sub-tropical coastal zone that stretches 580 km but with disproportionately large human settlement and an average 2 m diurnal tidal cycle that make the coast vulnerable to erosion.

Development in EThekwini increases bio-physical changes, leading to an escalation in environmental risks affecting coastal populations, infrastructure and natural coastal environments (eThekwini Municipality 2012). Bwaise III is a commercial and residential township, located in the north-western part of Kampala city in Kawempe Division. The ecosystem of Bwaise III is under threat from population growth but also erratic development, where plots of differing sizes are opened up for construction of housing, infrastructure, or industrial development without attention to conservation of green areas. Development would contribute to greater energy efficiency but fuel switching from inefficient traditional fuels to efficient modern fuels and devices, for example within residential and commercial properties, is yet to take shape in Bwaise (Okello et al. 2013). Charcoal is the preferred cooking energy, and adaptation strategies for energy scarcity have been devised at neigbourhood scale including self-generation (use of generators and solar panels), improved energy technologies (energy-saving bulbs and cooking stoves), adjustments in energy-use practices (abandoning boiling of water and foregoing hot water baths), adjustments in sleeping schedules, forsaking foods that require long hours of preparation alongside illegal theft and tapping of electricity (Mukwaya 2016). It is along these coping mechanisms that it was possible to embark on research with societal agents, and gather ideas and experiences about alternative energy that stems from the actions and ingenuity of waste vendors and green charcoal producers.

All three types of urban settlements have a deeply integrated type of informal economic activities with continued organic development of business premises and services that contrast with centralized systems used as the benchmark for measuring progress of a formal city in the urban north. The socio-economic and environmental characteristics of the three settlements stimulated empirical analyses of experimental practices which look across science, policy and societal domains, with the intention of providing an understanding of how science–policy–practice interfaces occur in African city settings. The empirical material consisted mainly of project reports and documents retrieved from the archives and websites that house materials on the three case studies. The documents were complemented with interviews amongst community co-researchers, academics and policy bureaucrats that were involved in three case studies. The interviews added in-depth knowledge on how the actors involved confronted institutional mandates that define the rules and regulations for collaboration. This uncovered the use of formal and informal pathways to co-design research agendas that redraw and stabilize the social boundaries between science, society and policy. Both academics and non-academics intuitively took on different roles including: coordinators, pen-holders, intermediaries and facilitators of joint learning and planning. Across the three case studies, the intermediary role involved acknowledging each actor's role through functional participation, whereas the facilitation required the academics to continuously promote openness and deliberation amongst the actors. Pen-holding pertained to documenting the outcomes of the co-framing and co-design processes, as the community co-researchers coordinated the process of making the different perceptions of local communities visible.

The case studies indicate a departure from highly institutionalized science–policy–practice interfaces in seeking to understand real-world sustainability challenges. The institutionalized modes are usually initiated by (1) a shared framework to support more systematic knowledge development and use, (2) identification of barriers that create a gap between stated urban goals and actual practice, and (3) identification of strategic focal areas to address this gap (Scholz et al. 2009; Seidl et al. 2013; Future Earth 2016). With limited formal leadership to engage with, science–policy–practice interfaces across the case studies were with both formal and informal actors and through an iterative mode for defining the roles of each actor from science, policy and societal domains, without basing on pre-determined guidelines, but rather semi-formal discussions of what it takes to engage in confronting sustainability challenges at local scale.

3 Experiments of science–policy–practice interfaces

3.1 Co-framing a research agenda on slum upgrading in Stellenbosch, South Africa

In 2011, as part of their postgraduate studies, a group of students from Stellenbosch University in South Africa agreed to research Enkanini, one of South Africa's urban slums with a population of 6000. The students' mutual research question was this: what does in situ upgrading (as specified by government program) mean in practice from the perspective of the average shack dweller living in Enkanini? With support from their academic supervisors, the students applied a transdisciplinary research approach as the avenue for changing the rules of engagement with societal actors, by way of establishing informal relationships with community actors in a settlement that is mostly devoid of formal structures. It is through such relationships that the study acquired both an emic and etic understanding and experience of what it means to live in a shack. By becoming activist-researchers and leading slum improvement campaigns, the students built relationships with residents across different demographics and peer networks, mainly the Informal Settlement Network, a social movement that worked with Stellenbosch Municipality officials who also had formal and informal contacts with the network.

The students' understanding of upgrading slums included municipal delivery of electricity for streetlights, water, sanitation, roads, storm water, and solid waste services. But this could only be possible if Enkanini met two formal standards by the municipal government: (1) it was recognized legally as a permanent settlement, and (2) the land on which it was located was zoned residential. As Enkanini met neither of these legal standards, a court issued an order for its removal, but with this was not enforced by the local authorities Even if the standards were met in Enkanini, upgrading meant waiting for waste-collection systems, electricity, and water grids to be put in place by the government. According to the Western Cape Provincial Government, this process could take about 8 years following legalization and rezoning. The research question changed to: what could be done before the arrival of the municipal services to improve quality of life? This reframing sparked the student's collective imaginations on alternative infrastructure solutions that could transform Enkanini. The postgraduates, who now had to combine university research expertise with the practical knowledge on Enkanini and the community groups, needed to form partnerships that had the ingenuity and capacity needed to make a difference. The students, working together in groups of two to three, came up with presentations for senior researchers within the university and municipal officials outside the university, who were supportive but suspicious about their endeavors. The students focused their presentations on research questions that treat scientific and societal knowledge with equal value in order find solutions to informal settlements. One of the students framed her research questions as follows:

1. How are social and technological considerations configured in the production of sanitation interventions in informal contexts?
2. What are the challenges of co-producing knowledge in an informal settlement context?
3. How can design facilitation enhance participation in contexts such as informal settlements that have traditionally been under-served by professional design?

As an industrial designer, the student argued that co-producing sanitation enables residents of informal settlements to situate their experiences within the academic research agenda, and taps into the spirited behavior of underprivileged citizens to lead intra-community and collaborative problem solving. Her presentation and that of colleagues, were refined into a transdisciplinary research enterprise that challenged the university to break out and use its resources, to build the capacity of other researchers to undertake collaborative studies that can incrementally bring about an improved shack instead of low-cost high-rise apartments. After months of informal and formal interactions between the university, municipality and the community, the iShack was designed by industry actors—a 14.2 m^2 dwelling incorporating fire-retardant insulation, passive heating and cooling materials, orientation to maximize solar penetration, a solar panel, and a gutter to capture rain water.

The iShack (Fig. 1) became the boundary technology for social engagement between the researchers and the community. These engagements changed the character of researchers and community values in ways that formed the guiding principles and design of the iShack Project. The project is now providing solar electricity, on a pay-for-use basis, to residents of an informal settlement in Stellenbosch (Enkanini), South Africa. Over 1500 clients have been targeted and a group of local franchisees have been trained and labelled as "iShack Agents". The agents install and maintain the solar systems and to market the service in their community. The clients pay a monthly fee for the service to ensure long term operational sustainability. The energy service provides lighting, television, cell-phone charging and additional energy for music, DVD players and radios. The utility is scalable

Fig. 1 Design of the improved shack in Enkanini-Stellenbosch, South Africa. *Source*: The iShack Project was pioneered by the Sustainability Institute of Stellenbosch University, 2016

and in future, fridges and water heaters will be added. This case study demonstrates how the replicated-practice of knowledge integration requires societal partners that can support a more agile learning environment for university students while converging the usual split between societal activism and scientific research.

3.2 Co-designing methodologies for a coastal vulnerability index in Durban, South Africa

After learning that encounters with beach erosion, coastal flooding, and other climatic impacts cannot be solved based on expert science alone, the city of Durban decided to build on the voices of actors at multiple scales in drafting a coastal vulnerability assessment. Memories of extreme storm events in March 2007 enabled local residents to construct narratives that shaped the co-design process of a local vulnerability assessment tools, as opposed to simply utilizing pre-formulated tools, which often render assessments expert-led and will neglect community-based knowledge. Local residents and municipal officials utilized mobile phones and digital cameras to take images of affected landscapes, buildings and communities. With facilitation by the experts, local actors distilled their experiences and developed a set of environmental, social, and economic indicators for co-designing a localized vulnerability assessment. Coastal geographers and consultants had initially designed tools depicting three sea-level rise scenarios: 300 mm (12 in.), 600 mm (24 in.) and 1000 mm (40 in.). By positioning local residents as co-designers of the vulnerability index, social, economic, built-environment, and physical characteristics were integrated into a single tool. The images taken and pictures drawn by the local residents were then placed on the right of each indicator. The socio-economic dimensions of the coastal vulnerability index (Table 1) made it a boundary object for enabling residents to easily visualize, interpret and associate their own experiences with expert and policy knowledge.

The content of the tool became cross-disciplinary in nature, with social, economic, geographical and environmental indicators that required both conventional expertise such as oceanography, and more recent disciplines like coastal sociology. However, there were limitations associated with a community-led process in co-framing the vulnerability assessment tool. The local elite were the voice for the non-elite, thereby concealing the realities of certain under-educated individuals, and experts did not critically inspect the process in

Table 1 Socio-economic dimensions of the coastal vulnerability assessment tool. *Source*: eThekwini Municipality, 2016; and author's aggregations of document and interview data, 2017

Type of risk	Socio-economic dimensions	Indictor for vulnerability assessment
Loss of property	Loss of beach holdings	Beach-based businesses operated by plot
	Tenure insecurity due to undocumented property rights	Number of affected persons with document and undocumented property rights by race and gender
	Deterioration in housing standards	Proportion of affected persons updated on municipal beach management laws by race gender (e.g. the Integrated Coastal Management Act)
Joblessness	Loss of merchandize by SME's (food stalls, artisanal units)	Number of affected SMEs by gender and race of proprietor
	Reduced income from natural resources (sand, quarries, fish)	Number of affected livelihoods depending on natural resources
	Conflict in and with SME associations	Number of SME associations involved
	Decline in production of staple crops (e.g. maize) as a result of climate change	Shifts in planting seasons
		Decline in crop harvest
Social disengagements	Loss of access to public services	Affected voluntary associations by settlement
	Loss of access to common property services (fishing grounds, cemetery, quarries)	Affected health units by settlement
	Dismantling of kinship, local voluntary associations, marriages, cultural clashes with host population	Common property services by village
Morbidity and mortality	Outbreak of vector-borne diseases/HIV/IDS	Number of illnesses reported
	Wife/husband buttering	Number of gender-based violence incidences reported
	Improvised sewage systems increase vulnerability to epidemics and chronic diarrhoea, dysentery	

order to allow the non-elite voice their experiences. But the lead scientists made an effort to have one-on-one interviews with the local actors whose voices had not been heard during the group work. To refine the vulnerability index, support was sought from Corporate Geographic Information System, used by the KwaZulu-Natal Provincial authorities and eThekwini Municipality. This enabled collation of societal and policy views within the vulnerability assessment tool, thus providing an apt context for co-expanding the social role of community-led design and innovation, given that purely technocratic approaches had failed to resonate with the lived experiences of costal dwellers in Durban.

Designers and geographers were enabled to become facilitators of a process in which participants visualized social, environmental and technical arrangements for confronting coastal erosion, and how these can be tested and improved collaboratively over time. Open-ended engagements gave room for flexibility so that changes can be absorbed in real time and continual learning is ensured. The community agents took on the role of provocateurs, who critically examined the societal relevance of the vulnerability assessment tool. By acquiring such a hybrid role, community agents were able to focus greater attention on social and cultural problems such as homelessness, insecurity, poor health, loss of property, social disarticulation and sanitation that are associated with coastal flooding and beach erosion. Although the initial tool had gone through a number of iterations to ensure that it is user-friendly to the municipality official and capable of generating scientifically accurate and credible information, it was largely focusing on storing climate change documentation produced by the Environmental Planning and Climate Protection Department and integration of the Geographic Information System tool, which spatially represents the climate change impacts projected for the eThekwini Municipal Area (projected mean annual temperature increase, and mean annual rainfall increase).

The integration of socio-economic, climatic and sea-level rise indicators facilitated the review of the Community Adaptation Plan Project that had been initiated in 2010. The solutions co-created included field trials for shifting planting dates and ensuring that crops are irrigated, as pathways for adapting to climate change conditions. Community members were also asked to taste food cooked using the alternative staple crops, like amadumbes, cassava, pumpkin and sorghum, in order to test the palatability and acceptability of these alternative crops. The field trial undertaken at Luganda School focused on controlling surface run-off that was eroding the school grounds and causing flooding. The selected interventions increased water storage on the school grounds with water being harvested off school-building roofs. This water is utilized by community members for their gardens as well as for a school vegetable garden which was established to provide vegetables to the school children. The banks of the school have also been stabilized with indigenous vegetation and vetiver grass to minimize flooding after heavy rainfall. This demonstrates how community-level climate protection planning and common sense can improve the lives of community members in a tangible way. These locally-embedded solutions speak to how substantial investments in co-produced adaptation science can facilitate substantial rates of implementation of adaptation actions. Therefore coastal erosion in Durban was the boundary subject for drawing in and bridging knowledge forms across expert scientists, local community actors and municipal offices, but without necessarily basing on past experiences from elsewhere thus depicting an anticipatory-practice for leapfrogging ocean health and sustainability.

3.3 Co-experimenting cleaner and affordable household energy in Kampala city, Uganda

Organic waste in Kampala including both human and solid waste is largely managed through practices that are environmentally unfriendly, which degrade aesthetics with adverse health and environmental outcomes making both city management and livability of Kampala challenging. However, organic waste is resourceful if utilized for nutrients recovery or turned into energy briquettes that can provide alternative livelihood strategies with a high potential for integrating the urban poor into the urban economy. Solid waste management interacts with climate system through generation of methane, which is highly potent that cumulatively contribute to Greenhouse Gases emissions. In Kampala, Kampala Capital City Authority (KCCA) is grappling with managing wastes and the model which has been pursued for long is the collect, transport, dispose wastes at a landfill with several challenges including accumulation of leachates, contestations from the community close to the landfill and waste picking that is often seen as scavenging. Knowledge exists on generation, management practices, and environmental problems, costs incurred by KCCA and costs to communities and the largely engineering solutions. But the knowledge about the transformation of organic wastes into usable products has remained at micro scale in communities where research and pilots have been undertaken in the last two decades. The alternative means of managing the organic waste by turning it into resourceful products such as energy briquettes is estimated to recover less than 5% of the organic wastes generated in the city if transformation of bio-waste is done at or near the source of the bio-waste, to reduce volume and bulk, and optimize transportation costs (Table 2).

A research project known as Augmenting Waste Economies (AWELIS), was designed to enable demonstrable strategies for transformation of waste management in the city. A research team of four community representatives from Kasubi-Kawaala parish, two policy actors from Kampala Capital City Authority (KCCA) and four academic researchers from Makerere University Uganda, co-designed their research question as: what does energy efficiency for environmental health mean in practice from the perspective of the average household agent living in Kasubi-Kawaala neighborhood? With a research question that is scientifically-relevant and socially-valuable, data gathering was initiated through unstructured interviews coupled to twelve (12) focused-group discussions,

Table 2 weighting of waste to fuel conversions in Kampala city. *Source*: Author's review of a research project on augmenting waste economies in Kampala city, January 2018

Bio-waste stream	Weight loss during briquette-making (%)	Time for boiling 10 l of water (min)	Burning duration (min)
Maize cobs	75	25	300
Banana peelings	83	20	330
Potato peelings	77	30	270
Food waste (maize)	70	25	250
Mushroom waste	50	35	180
Cow dung	65	25	250
Saw dust	36	35	210
Charcoal dust	0	35	240

comprising of respondents in from seven (7) groups of informal waste vendors and green charcoal producers (Table 3). A check-list of questions was used to permit social learning and engagement pertaining to practice-based challenges for transformation of waste management in the neighborhood. The questions were centered on: (1) how to enable transition of the current micro-scale interventions of energy briquettes to meso and macro-scale within the context of Kampala city-region; and (2) was how to enable development of products and business model that can have double edged outcomes of mainstreaming the urban poor into the urban economy while reducing the adverse health effects of indiscriminate dumping and management of wastes in the city. These questions became the boundary subject for social engagement and learning among the academic researchers, community representatives and officials from Rubaga Municipality of KCCA.

With support from community representatives, academic researchers established informal relationships with the neighborhood associations. It is through such relationships that the study acquired both an emic and etic understanding and experience of what it means to access energy and health services in Kasubi-Kawaala. By becoming embedded-researchers that participate in initiatives undertaken by low-income groups to extract and add value to materials from the waste stream, through the use of organic waste for nutrient recovery and production of energy briquettes, the neighborhood associations were able to narrate their own life course, as the act of telling a story that is strongly linked with the process of immersion into experimentation of waste recycling for production of energy briquettes. Interviewees talked about their energy biographies, going back to their earliest memories, and through these narratives it was possible to recreate the actions of waste vendors and green charcoal producers. However, the aim was precisely to reconstruct their lived experience, invested with meaning as it is, and, therefore, to learn about the shifts in the roles of actors and approaches to co-designing experimentation of sustainable energy transitions in an informal settlement. Interviews lasted for 3 h each on average and were all conducted by academic researchers in the presence of community co-researchers.

Dialogues with the local community representatives revealed that there are neighborhood-scale innovations and groups (Table 4) that seek to balance the need for energy and urban environmental health protection through organic and inorganic waste re-use and recycling. This involves recovering re-usable and recyclable items from the waste stream including: polythene bags for growing mushrooms; banana–cassava–sweet potato peelings and cow dung for compost; plastic bottles for packing juice and drinking water; newspapers for making tray eggs; tins and mineral water bottles for making shoe soles; bottle straws for knitting baskets; charcoal and saw dust for reducing odor from latrines; oily milk packages used as fuel for cooking; discarded cardboard serving as walls and roofs of houses for a cool indoor climate. The most common waste innovation marketed by all these types of groups are garbage briquettes. These are created when banana peels and other dried organic material is put into a large bin and then burned at high heat and low oxygen which creates a kind of charcoal material but made out of garbage instead of trees. This is then crushed and mixed with clay and cassava flour (as a glue) and rolled into balls to create briquettes that can be used instead of charcoal. One actor from Kasubi Community Development Association (KACODA) reported that 10 kgs of saw dust are mixed with 4 bottles of mushroom seeds together with 20 l of water and rice husks, stirred, cooked and then left to decompose for 6 months so as to have fertilizers. The resultant volume of fertilizers can enable the farmer establish 60 mushroom gardens of 4 × 4 square meters that can fetch a daily income of USD 15. It was noted that this innovation is a technological transfer from India, and the yields from this kind of technology provide curative medicines for heart

Table 3 Neighbourhood groups active in Kampala's waste economy. *Source*: Dialogue with local community representatives, November 2017

Name of group	Waste economic activities	Location in Kampala
Kisensu	Drainage maintenance and drawing silt from Kiwunya Stream, collection of plastics, water harvesting	Makerere ii zone C
Kasubi parish local community initiative	Sensitization on waste separation, water harvesting, collection of plastic bottles	Makerere ii zone B
Community life skills empowerment and development centre	Collection of plastics, banana peelings for sale, sorting charcoal dust, and cow dung	Namungona
Joint community development initiative	Garbage collection, protection of the spring, water harvesting	Kasubi-Kawaala
Kasubi community development association	Sorting charcoal dust, cow dung, garbage collection, transportation and disposal	Kasubi-Kawaala

Table 4 Levels of science–policy–practice interfaces. *Source*: Aggregation of reviewed literature and learning experiences from case studies in African cities

Levels	Forms of interaction	Purpose of interaction	Roles of stakeholders
Level 1: Science *for* policy and practice	Single one-way interaction	"Informing": relevant information from study results are communicated from one side to the other (science to practice and/or science to policy)	Scientists are the producers and disseminators of knowledge
	Multiple one-way interactions	"Informing across sectors and scales": scientists exchange relevant information from studies with policy-makers and practitioners at city, national, regional and global scale, and the policy-makers and practitioners are drawn from different sectors such as health, transport, housing and energy	Policy-makers and practitioners are the targeted end-users of knowledge
Level 2: Science *with* policy and practice	Collaborative research	"Co-framing research agendas and co-designing methodologies": scientists from different disciplines work with practitioners and policy-makers across sectors and scales, to define the research problem and methodology, and go ahead to work hand in hand to generate and disseminate the results	Scientists, policy-makers and practitioners are co-producers, co-disseminators and co-end users of knowledge
	Joint decision making and implementation	"Co-experimentation and joint action for change": scientists from different disciplines not only undertake research with practitioners and policy-makers across sectors and scales, but also jointly create, test or take to scale solutions with the aim of bringing about transformative change in society	

disease. This provides an insight on how the waste economy can contribute to harnessing the health co-benefits of energy efficiency.

Another experiment is the generation of bio-gas from organic waste. This experiment is relevant for Kampala city because KCCA spends an estimated 1/3 of its annual budget to managing wastes, 3/4 of which are organic and if turned into energy, KCCA would save, communities would gain businesses and users would have a reduced per capita emissions which at the moment stands at ~ 200 g per person per year (KCCA 2018). The local community actors acknowledged that if the generation of bio-gas kicks off substantially, energy will be generated from solid waste will be generated. The official argued that this can enable Kampala city generate what is required for daily consumption and the remainder is sold to neighboring districts for revenue generation. But knowledge about the transformation of organic wastes into health-friendly energy products has remained at micro scale in communities, even where research and pilots have been undertaken. And yet the transition of micro-scale interventions of energy briquettes to meso and macro-scale, would not only integrate the urban poor into the urban economy but also reduce the adverse health effects of indiscriminate dumping and management of wastes from energy-related activities. The scalable nature of local waste practices amongst unregulated networks of neighborhood groups, offered co-benefits to health and poverty-oriented energy transitions at neigbourhood scale.

4 Discussion

Across the case studies, it can be argued that science–policy–practice interactions for sustainable urban development, do not call for linear processes or models, where research results are arranged into policy options that can be tabled before decision-makers practitioners. Rather, science–policy–practice interactions unfold through three parameters, which are: (1) co-framing research agendas; (2) co-designing methodologies for generating and use of knowledge; and (3) co-experimentation of scalable local innovations. Co-framing research agendas starts with identification of the key urban issues and challenges by stakeholders from science, policy and practice agencies. Joint identification of the urban challenges may be limited to one or several urban sectors, followed by consensus on the priority urban sustainability challenge(s) to be confronted a given city or country or region. The priority challenge(s) is co-framed into research questions that contain scientific, policy and societal elements.

Within the parameter of co-designing methodologies, scientists, urban practitioners and policy-makers exchange their respective knowledge on the best means possible for executing an urban research agenda. Co-designing methodologies does not necessary mean building consensus around the tools for data collection and analysis, but rather it requires joint effort on developing mechanisms that will permit the generation, integration and sharing of knowledge that is scientifically credible and valuable to society and in policy-making processes. The mechanisms are co-designed through reflections and iteration amongst participating scientists, practitioners and policy-makers, to identify a set of interventions for generating knowledge, dissemination and use. For instance, co-designing methodologies for dissemination can mean opening up discussions on the multiple ways of packaging study results into forms that are digestible for decision-makers in government. Co-designing methodologies therefore means that scientists, local communities and policy-makers become peer researchers on feasible mechanisms for providing knowledge that is better able to contribute to the development of robust policy solutions and their effective implementation.

Co-experimentation focuses is on what can be tried or taken to scale for sustainable urban development to become a reality. Co-experimentation is not only collaborative like the other two parameters, but also transformative in orientation, requiring knowledge that demonstrates that is possible to escape challenges such as urban poverty, inequality and climate change. In this parameter, scientists, practitioners and policy-makers collaborate to generate locally-embedded solutions (which can be in form of technologies, policy frameworks or standard tools) that can facilitate gradual or robust societal change. Such solutions can stem from micro-scale experiments (that might or might not work) that are situated at the intersection of different urban sectors, and in anticipation of broader systemic change. Co-experimentation calls for a recursive process of social learning to explore and find alternative, innovative pathways to bringing about policy and social change. Such learning can for instance happen in the local community, where policy-makers are invited to witness the evolution or replication of local solutions in the presence of scientists and other intermediaries of knowledge (for example NGOs), with the purpose of generating knowledge on the urban policies needed to seize the scale-up potential of such local innovations.

5 Conclusion

As shown in Table 4 below, the parameters can be discerned at two levels interfaces amongst actors from science, policy and local communities. The first level is science *for* policy and practice, and the second level is science *with* policy and practice. Science *for* policy and practice is conventional in nature, where scientists are the producers of knowledge whereas policy-makers and urban practitioners are the targeted end-users of knowledge. In this situation, scientists conduct research and take the results to policy-makers and practitioners for discussion and adoption after completing the research process. Science *with* policy and practice on the other hand, is where scientists, policy-makers and urban practitioners have an equal chance to be producers of knowledge. The position of policy-makers and practitioners changes, from end-users to co-bearers of knowledge with scientists. Although the two levels of interface provide an environment for engagements amongst scientists, practitioners and policymakers, science *with* policy and practice offers a better understanding of the organizational arrangements that effectively influence the three parameters, that is: (1) co-framing research agendas; (2) co-designing methodologies for generating and use of knowledge; and (3) co-experimentation of scalable local innovations. Such organizational arrangements relate to variances in targeted sectors and geographical scales. The sectors determine the urban sustainability vision agreed-upon for joint research and learning. For instance some of the sustainability visions experimented upon are uni-sectoral (focusing on one urban sector and the sub-sectors therein), while others are multi-sectoral (focusing on different sectors). The geographical scale (neigbourhood, city, city region, inter-city, national and global scales) is key in defining the ways through which the hierarchies between the academics, policy-makers and community agents are flattened, to lessen the possibilities of unequal power relations in the process of collaboration and joint decision-making.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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