ARTICLE

Check for updates

Fostering transdisciplinary research for sustainability in the Global South: Pathways to impact for funding programmes

Flurina Schneider [1,2,3,4 ✉], Zarina Patel [5], Katsia Paulavets[6], Tobias Buser[7], Jacqueline Kado[8] & Stefanie Burkhart[2,4]

Advancing global sustainable development hinges on strengthening the connections between science, society, and policy, as well as addressing existing science inequalities. Research funding programmes play a pivotal role in this context, but little is known about how they can actively nurture required transformations of the science systems. In this paper, we investigate how science funders can actively promote science-society-policy interactions through transdisciplinary research (TDR) as a means to advance sustainable development in the Global South. Our primary focus is on the research funding programme "LIRA 2030 Africa". Our research has revealed three closely intertwined pathways for cultivating TDR in this context: (1) Enabling African scientists to lead high-quality TDR projects, (2) empowering African scientists to pursue a career as TDR researchers, and 3) enhancing the context conditions for doing TDR in Africa. By scrutinising the advantages and challenges associated with these pathways and their associated activities, we conclude that fostering TDR in Africa necessitates a multifaceted approach. This approach entails a combination of measures, such as providing research grants, offering TDR and leadership training, fostering networks, developing institutions, and facilitating collaboration across various funders.

[1] Faculty of Biosciences, Goethe University Frankfurt, Frankfurt, Germany. [2] ISOE - Institute for Social-Ecological Research, Frankfurt, Germany. [3] Centre for Development and Environment (CDE), University of Bern, Bern, Switzerland. [4] Senckenberg Biodiversity and Climate Research Centre SBiK-F, Frankfurt, Germany. [5] Environmental and Geographical Sciences, University of Cape Town, Cape Town, South Africa. [6] International Science Council, Paris, France. [7] Global Alliance for Inter- and Transdisciplinarity (ITD Alliance), Bern, Switzerland. [8] Network of African Science Academies (NASAC), Nairobi, Kenya. ✉email: flurina.schneider@isoe.de

Introduction

Policy visions, such as the United Nations Agenda 2030 ("Transforming Our World") and the African Union's Agenda 2063 ("The Africa We Want"), identified science as critical means for advancing sustainable development. Whilst the pivotal role of science in generating relevant knowledge for sustainable transformations is gaining traction across science and policy communities globally, research in the Global North and South are providing evidence of vast differences in the potential of science to drive ongoing transformations in a sustainable direction (Fazey et al. 2020; Llopis et al. 2020; Messerli et al. 2019; Schneider et al. 2019; UN GSDR, 2019). This paper responds to the need of transforming science systems to foster transformative change in African cities.

We focus on two challenges that should be addressed within science systems: 1) The need to strengthen science-society-policy interactions and 2) the need to tackle existing science inequalities between research in the Global North and South. Transdisciplinary research (TDR) is increasingly recognised as a useful approach for improving these interactions (Jahn et al. 2012; OECD, 2020; Schneider et al. 2019), whilst the need to support and amplify research capacity of the Global South is seen as a priority in fostering global science and education systems that are equitable and context relevant (Atindehou et al. 2019; Maassen, 2020).

The way science funders design their research funding programmes, plays a significant role in determining how TDR is conducted, and where and how investments in science capacity are utilised. This article aims to contribute evidence on how science funders can achieve the dual role of fostering science-society-policy interactions, whilst simultaneously tackling science inequalities through capacity building. More specifically, the question is how research funding programmes can foster TDR for advancing sustainable development in the Global South. The focus is the research funding programme of the International Science Council (ISC): Leading Integrated Research for the Agenda 2030 in Africa (2017–2021) – LIRA 2030 Africa. By focusing on the benefits and challenges presented by the programme's pathways to foster TDR and associated activities, this paper contributes to debates on the scale and scope of transformations of science and higher-education systems in Africa and the role of science funding.

Transdisciplinarity and the role of research funding programme designs. TDR aims at linking scientific knowledge production and societal problem solving in processes of knowledge co-production. It is "a reflexive research process that addresses societal problems by means of interdisciplinary collaboration as well as the collaboration between researchers and extra-scientific actors; its aim is to enable mutual learning processes between science and society" (Jahn et al. 2012). TDR has been developed as scholars realised that traditional ways of disciplinary knowledge production are insufficient to accommodate the complexity, uncertainty, and contested nature of sustainability challenges (Hirsch Hadorn et al. 2006; Huutoniemi, 2014; Jahn et al. 2012; Schneider et al. 2019). In these situations, researchers from social and natural sciences need to collaborate with various societal actors throughout the research process in order to jointly generate the knowledge needed to act towards sustainability. Consequently, TDR is often depicted as an ideal-typical process composed of three phases: Phase A 'collaboratively framing the problem and building a collaborative research team'; phase B, 'co-producing solution-oriented and transferable knowledge through collaborative research'; and phase C, '(re-)integrating and applying the produced knowledge in both scientific and societal practice' (Lang et al. 2012).

Over the years, a considerable body of literature has emerged about TDR on the project level (e.g. Culwick and Patel, 2017; Schneider and Buser, 2018; Stauffacher et al. 2008; van Breda and Swilling, 2019). One key conclusion of these studies is that TDR requires conditions that differ from those needed for basic disciplinary research (e.g. regarding time, skills, and resources for collaboration, review processes, career incentives (Dedeurwaerdere, 2013; Kläy et al. 2015; Kueffer et al. 2012; OECD, 2020; Roux et al. 2010; Schneidewind, 2009)). For example, Barth et al. (2020) stressed that TDR requires additional knowledge and skills, which are usually not covered by traditional higher-education curricula (e.g. methods for knowledge integration, competences for stakeholder interactions). Bromham et al. (2016) found that TDR proposals have difficulty in obtaining funding. Reasons for this are: (a) Despite a widespread call for TDR, most research funding instruments are structured along disciplinary lines (Woelert and Millar, 2013); (b) reviewers tend to apply disciplinary quality criteria when assessing them (Mansilla, 2006); and (c) when successfully evaluated, typical TDR components, such as joint problem framing or stakeholder collaborations, are often not covered by the traditional funding instruments (Matso and Becker, 2014; Schneider et al. 2019). Finally, Patel (2019) and Van Breda et al. (2016) stressed that TDR careers of young TDR scholars can be at risk, because classic academic career metrics still heavily favour publications in academic disciplinary peer-reviewed journals, whereas contributions to societal transformations, such as, capacity development, social and institutional learning, engagement with policy and the public, and relationship-building, are less valued. Consequently, many scholars have stressed that for TDR to reach its full potential, not only suitable methods and epistemological foundations are required, but also fundamental institutional changes in its governance and funding structures (OECD, 2020).

As a consequence, while the broader research funding landscape remains organised along disciplinary lines, several national and international research funding bodies started to develop dedicated funding programmes promoting TDR (e.g. Belmont Forum, Europe's Horizon 2020 programme, or Germany's Research for Sustainable Development (FONA) initiative). However, to date, relatively little evidence exists on how research funding programmes can effectively foster implementation of TDR, in particular in the Global South (Arnott, Kirchhoff et al. 2020; Lyall et al. 2013; Schneider et al. 2019).

Researchers studying such funding programmes identified several areas of influence that are important for improving the conditions of grantees to successfully undertake TDR. The areas of influence include solicitation conditions, proposal review, funding coverage, building of TDR capacity, implementation support, and evaluation and learning (Arnott et al. 2020; Lyall et al. 2013; Matso and Becker, 2014; Schneider et al. 2019). Involvement of societal actors in related activities is considered key, e.g. in evaluating research proposals or impacts (Mach et al. 2020; Schneider et al. 2019). In addition, there are several factors that affect successful navigation of the overall funding programmes, including identification of the appropriate place/locus of TDR, knowledge integration as a deliberate step throughout the programme, inspiring leadership, and active management (Lyall et al. 2013).

Although empirical research is still limited, an increasing number of studies have examined activities of individual funding programmes in relation to specific areas of influence. For example, Arnott et al. (2020) tested if changes in solicitation conditions encourage interactions between researchers and societal actors, and Hoffmann et al. (Hoffmann et al. 2017) examined the process of knowledge integration. Others focused

Table 1 Overview on the ten key stages according to Schneider et al. (2019).

Key stages	Short description
1. Programme preparation	In this stage, the overall parameters of the programme and the future research are set, namely the research and transformation goals, pathways to impact, as well as available funds. By outlining the research requirements, it also defines the room for manoeuver applicants have in designing and implementing TDR processes within specific projects.
2. Project proposal elaboration	In response to the programme call, the research consortia then prepare and submit project proposals specifying their goals, research questions, and methodological approaches.
3. Interactions with applicants	During proposal writing, research programmes interact with their applicants in different ways (e.g. communication of call requirements, preliminary feedback, coaching).
4. Project selection	In this stage, the programme evaluates the proposals and decides which projects will be included in the programme, what is expected of them, and how much funding they will receive.
5. Research activities	The approved research projects implement the TDR described in their proposal.
6. Joint agenda setting	Any research programme seeking to work towards transdisciplinary synthesis on behalf of overall programme goals should include a joint agenda-setting stage at the very start of the research programme.
7. Networking and integration	Networking and synthesis activities may be regarded as the core processes of TDR at the programme level.
8. Interactions with participating projects	Supportive interactions with participating projects is an ongoing task aiming to support the TDR work of individual projects as effectively as possible. It can range from providing clarifying information about basic requirements and offering targeted trainings to setting up adequate monitoring systems for evaluation of individual project performances.
9. External communication and transformation	In a TDR programme, this stage goes beyond classic activities of knowledge transfer, such as communicating research results to society in a one-way process. It involves diverse and collaborative forms of interaction, such as knowledge exchange, joint learning, and transformative practices.
10. Programme conclusion & impact evaluation	The concluding stage of a TDR programme includes communication of final results, but also the handover of responsibility to other suitable actors capable of carrying on the initiated work needed to contribute to societal transformations. In addition, evaluation of scientific and societal impacts should be part of any large research programme.

on the overall design of research funding programmes. For instance, Schneider et al. (2019) developed a model that highlights three overlapping phases and ten key stages within a lifecycle of a research funding programme that require special consideration to foster TDR throughout that programme. The stages address various areas of influence described above: Programme preparation (incl. call), project proposal elaboration, interactions with applicants, project selection, research activities, joint agenda setting, networking and integration, interactions with participating projects, external communication and implementation, programme conclusion and evaluation (see Table 1). Reflexive application of the model is intended to help funding agency staff in identifying the key stages in a funding programme that require special consideration in order to improve conditions for TDR. However, the model does not specify how the identified stages should be designed and implemented in distinct contexts. The authors of the model argue that this depends on the particular programme's thematic focus, goals, epistemological assumptions, contextual factors and envisioned pathways to societal impact (impact pathways describe a research programme's assumptions about how it might contribute to societal transformations).

Research capacity in Africa. The global distribution of research capacity is very unequal (Messerli et al. 2019; UN GSDR, 2019), be it regarding classical science metrics, such as number of researchers, publications, access to publications, funding, research infrastructure, (Beaudry et al. 2018; Maassen, 2020), or regarding TDR capacities more specifically (Belcher et al. 2016; Newig et al. 2019; OECD, 2020). This is particularly true for Africa. While many African research institutions have increased their research capacity in recent years (Kinyanjui and Fonn, 2020) – Africa's share of world science, as measured in published papers, doubled from around 1.5 to 3% over the past 10 years (Mouton and Blanckenberg, 2018) – overall research productivity is still lower

compared to other parts of the world (Maassen, 2020; Ngongalah et al. 2019).

Reasons explaining these imbalances are multifaceted and include – but are not limited to – aspects ranging from historically grounded inequalities going back to colonial times, current funding priorities of national governments, lack of stable scientific institutions, to brain drain (Kozma et al. 2018; Mouton, 2018; Sheikheldin and Mohamed, 2021). Although many African governments expressed strong commitment to strengthen the science systems by increasing research funding (e.g. Agenda 2063, (African Union Commission, 2015), the research expenditures of many (sub-Saharan) African governments are still less than 0.5% of their GDP (Mouton, 2018). This results in multiple challenges. First, African scholars are regularly challenged by under-resourced and weak institutional structures, including unstable budgets and administration support, inadequate quality of research infrastructures and education facilities, and high teaching loads, all negatively impacting their research productivity (Beaudry et al. 2018; Mouton, 2018; Ngongalah et al. 2019; Sheikheldin and Mohamed, 2021). Second, African scholars often depend on international funding that reinforces the influence of the Global North on setting research agendas (topics and practices), which often have little resonance with the African realities (Harle, 2016).

Furthermore, the prevailing science metrics disregard science-internal as well as social processes and poorly recognise and reward scientific contributions that focus on local issues of social relevance (Maas et al. 2021): Researchers of the Global South directing their capacities to issues of local societal benefit can lead to less receptive scientific environment concerning global issues (Biermann, 2002; Chataway et al. 2019; van Jaarsveldt et al. 2019). Consequently, they tend to be indirectly excluded by self-reinforcing global academic networks that are known to enhance publication rates of certain authors while indirectly excluding others (Maas et al. 2021). Publication of scientific results in other than English languages, and the general underrepresentation of

scientists from Africa in editorial boards are among other factors that affect appropriate recognition of African scientific work (Nuñez et al. 2019).

The situation is particularly challenging for early career scientists, because there are limited career opportunities, lack of postgraduate programmes and fellowships, mentoring and training, and restricted access to the scarce funding schemes (Beaudry et al. 2018; Maassen, 2020). Consequently, up to 30% of highly qualified African scholars leave the continent every year to take over positions in other countries leading to brain drain (Mouton, 2018). Currently, there are more African PhD holders outside the continent than inside (Sheikheldin and Mohamed, 2021).

These existing science inequalities are putting Africa at disadvantage in achieving sustainable development. Against this background, several authors argued that massive financial investments in research capacities are needed by both, national governments and international funders, in order to enhance research capacities for contributing to sustainable development in Africa (European Commission, 9.03.2020; Maassen, 2020; Messerli et al. 2019; UN GSDR, 2019). This is relevant for science in general, but is even more crucial for TDR: Undertaking this type of research requires strengthening related capacities (ISC, 2020). Although alternative funding prioritising TDR has emerged in recent years, most research funders are not yet effectively supporting this type of research.

Questions, case study and methodology

To address our overall research question of how research funding programmes can foster TDR, we seek to answer the following sub-questions (RQ):

RQ1: Through what pathways can a research funding programme foster TDR for sustainable development in Africa?

RQ2: How did the LIRA programme shape its design and activities to advance these envisioned pathways?

RQ3: What were the benefits and challenges of the programme's design and activities for fostering TDR?

Case study. The key goal of the studied research funding programme LIRA 2030 Africa is to increase the production of high-quality, solutions-oriented, and policy relevant knowledge on sustainable development in African cities and to build a new generation of scientists with the ability and capacity to produce and communicate this type of knowledge. Its distinctive feature is that it promotes TDR in a specific urban context in Africa (ISC, 2020).

The programme is funded by the Swedish International Development Cooperation Agency (Sida) and delivered by the International Science Council together with its Regional Office for Africa (ISC ROA), and the Network of African Science Academies (NASAC) from 2016 to 2021.

Since the programme started, it has launched three calls on different sustainability themes: (1) Understanding the 'energy-health' and 'health-natural disasters' nexuses in African cities (2016); (2) Advancing the Sustainable Development Goal 11 in Africa (2017); and (3) Pathways towards Sustainable African Urban Development (2018). Resulting from these calls, the programme has funded three cohorts, 28 research projects in total up to the value of €90,000 each over the course of two years.

Each project brings together cities in two African countries to foster learning across cities and research collaboration across research institutions in Africa. Ensuring the participation of low-income countries in research collaboration was particularly emphasised.

The programme's total funding volume is ~5 million Euros over the course of six years, whereas over 60% of the total funding is allocated specifically for TDR projects. Additionally, the projects are supported by the programme through various other resources, such as training, peer-learning and networking activities (ISC, 2020).

Method. Our research is embedded in a learning study accompanying the LIRA programme. The core team of the learning study consisted of two TDR experts and two programme managers, one from Africa and one from Europe each. Hence, our research was guided by what Burawoy (1998) calls a "reflexive model of science", which considers engagement with, rather than detachment from the object of investigation as the suitable approach to generate new knowledge. In this research approach, scientists and 'reflective practitioners' (Schön, 1983) co-generate new knowledge by combining established methods of social sciences with structured methods for self-reflection (Lang et al. 2012; Schneider et al. 2019). Hence, this method differs from classical programme evaluation studies were independent researchers evaluate the performance of a programme. The advantage of our approach is that the study team embraces both, independent researchers as well as practitioners deeply knowledgeable about the investigated structures and activities. Combining rigorous scientific analyses with the knowledge of the involved practitioners helps generate truly actionable knowledge (Nowotny et al. 2001; Schneider et al. 2019). However, our approach also bears the disadvantage of possible blindness to alternative interpretations due to reduced distance between researchers and research object.

To address our research questions, we used a case study approach, which combined interviews, surveys, document review and participatory observation. To understand the programme's envisioned pathways to foster TDR and implemented activities (RQ1 and RQ2) we conducted a qualitative content analysis (Flick, 2005) of programme documents (e.g. calls for project proposals, programme proposal, annual programme progress reports) and of expert interviews with programme representatives (the management team and three members of the scientific advisory committee). Based on these insights, we mapped key programme stages and activities over time by using the generic model of a TD research funding programme as developed by Schneider et al. (2019) (see Table 1).

To assess the benefits and challenges of the programme's activities (RQ3), we used data gathered through participatory observation, formal post-activity evaluations (e.g. evaluation of a single training course by grantees), programme monitoring (e.g. annual programme progress reports), a survey conducted with all grantees at project end (total 27), as well as the interviews with the programme representatives mentioned above. This data was assessed using qualitative content analysis and descriptive statistics (doi.org/10.5281/zenodo.8238102), and attributed to the programme stages identified before. Finally, we reassessed the information gathered according to the programme stages against the background of the three identified pathways to foster TDR. The generated data allowed to understand the benefits and challenges as perceived by the grantees and programme representatives. Perspectives and impacts beyond these sources could not be considered.

Findings

In the following, we present our findings along the three identified pathways to TDR impact. Each pathway outlines a set of key assumptions that the programme deems essential for fostering TDR in Africa. The first pathway centres on enabling individual
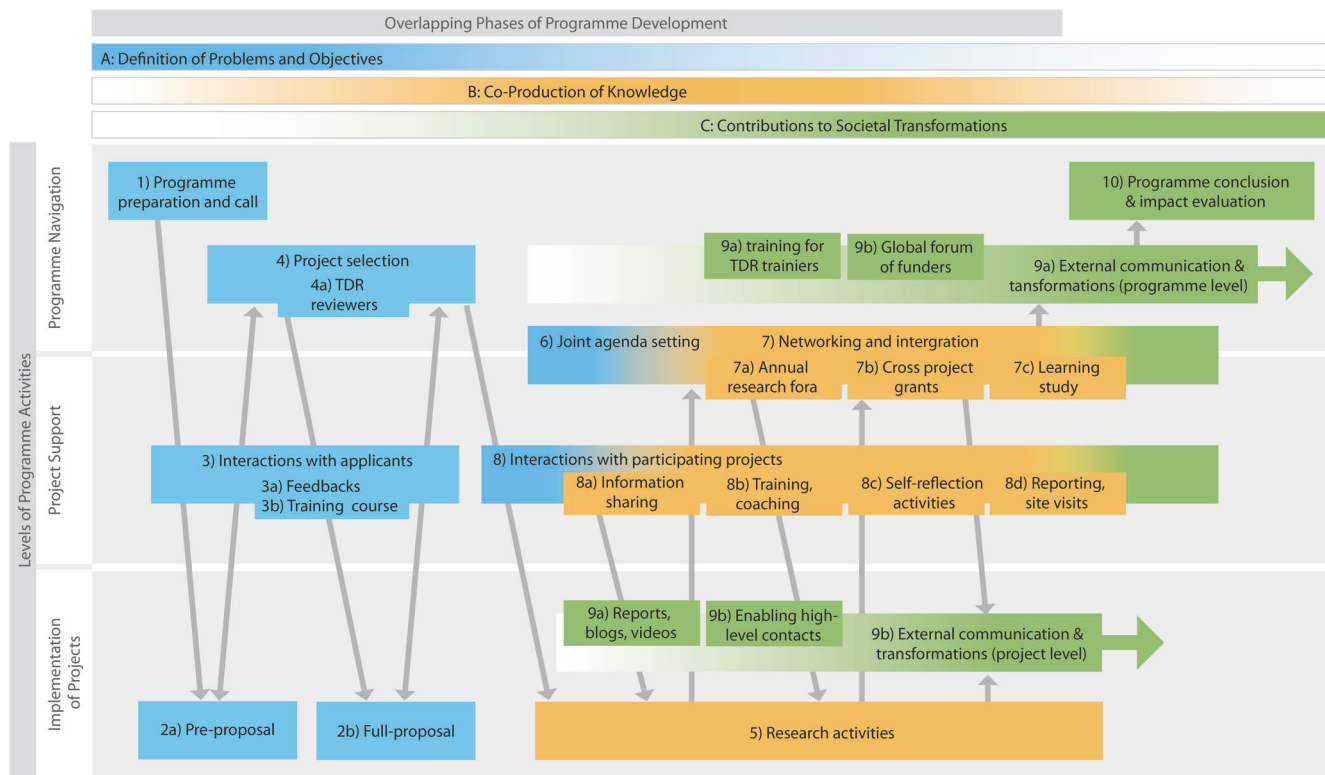
Fig. 1 Overview on key stages and activities of the LIRA funding programme. The numbered panels show the ten key stages along the three phases of programme development (**A**–**C**) and levels of programme activities (programme navigation, project support, implementation of projects); the colors stand for the three phases (blue: A, yellow=B, green=C); the arrows indicate the interactions between the stages (adapted from Schneider, Buser et al. 2019).

early-career scientists to acquire the funds and skills needed to lead high-quality TDR projects. The second pathway emphasizes the career progression of TDR scientists beyond the project level. Lastly, the third pathway explores the institutional context in which TDR scientists are integrated. Although these pathways are distinct on a conceptual level, certain programme design features and activities can contribute to the advancement of more than one pathway and the pathways reciprocally strengthen each other.

An overview on the programme's design and activities is shown in Fig. 1.

Pathway 1: Enabling African early career scientists to lead high-quality TDR. The first identified pathway to foster TDR in Africa (RQ1) is to enable African early career scientists to lead high-quality TDR sustainability projects through provision of dedicated funding and capacity building. The programme assumed that the young scientists need not only funds, but also additional knowledge and skills to develop, conduct and lead high-quality TDR projects in a successful way.

To advance this pathway (RQ2), the programme decided in stage 1 (programme preparation) to combine collaborative research grants that dedicate substantial funding for knowledge co-design and co-production, and capacity building activities covering all phases of TDR.

The grants were announced in three calls, one per year. Each call was developed by a scientific advisory committee composed of prominent African scientists. The calls were explicit that the grants are for TDR projects, and included details of the solicitation conditions, review criteria and funding coverage (see Table 2). Regarding TDR, the calls mentioned namely that participation of social and natural scientists are obligatory, research questions must be co-designed with key stakeholders, and a convincing

communication/outreach/engagement approach must be presented. After each call, a meeting between the scientific advisory committee and the programme management took place to reflect on the lessons learned and improve the consecutive calls. For instance, as applicants of the first call found it difficult to understand what was meant by TDR, more guidance and links to key TDR literature were given in the second and third calls.

The grant application process (stage 2–4) was organised as a two-step process of pre-proposals and full proposals, with a five-day TD training course in between. The key objectives of this process were to provide the applicants time to (1) build meaningful inter- and transdisciplinary teams, (2) undertake initial co-design of research questions, and (3) build scientific capacity to develop high-quality TDR full proposals. Compared to other funding programmes, interactions with the applicants during the grant application process were rather intense and involved, in addition to the training course, detailed feedbacks on the pre-proposals. In total, 475 pre-proposals, and 98 full-proposals were submitted.

To identify the most promising TDR projects, the proposals were assessed using the review criteria shown in Table 2, and efforts were made to identify reviewers with TDR competences. However, only a handful of TD experts could be identified to undertake this task. Consequently, to do justice to the TDR character of the proposals, thematic experts from different relevant disciplines and practitioners were selected – in total, three reviewers per proposal. Based on the expert reviews, the scientific advisory committee selected a set of fundable projects and advised the ISC on the final funding decision. Finally, 28 projects were awarded involving 22 African countries.

Within the funded projects, the TDR approaches were diverse and ranged from singular engagements with specific stakeholder groups (e.g. in the form of policy dialogues), to engagement of

Table 2 Solicitation and review criteria, and funding coverage.

TDR solicitation criteria detailed in the calls	• In line with the thematic focus of the call • Collaboration between early career scientists across scientific disciplines, participation of one natural and one social scientist was obligatory • Research questions should be co-designed with key stakeholders • Co-production of knowledge with key stakeholders • Research collaboration across Africa (each project should involve 2 African countries)
Review criteria	• Relevance to the call • Scientific merit (focus on quality rather than excellence) • Potential research impact • Interdisciplinary skills mix of projects teams • Collaboration with non-academic stakeholder groups • Research collaboration at the regional level • Adequacy of communication/outreach/engagement approach • Gender equity in research content and practice
Funding coverage	• Direct research costs (up to 35% of the grant) • Knowledge co-design and co-production (up to 25% of the grant) • Activities related to translating research into policy and practice (up to 15% of the grant)

other stakeholders and interdisciplinary expertise at several stages in a project timeline (stage 5) (for more details see Patel et al., 2022).

TDR was an integral part of the programme's monitoring and reporting system (stage 8). The progress reporting template included questions related to TDR, which were designed to stimulate regular reflections within the project teams on their TDR experiences and to document progress and learning. As a consequence of the evolving programme design, projects of the second and the third cohorts were also asked to conduct a custom-designed 'self-reflection activity' with their whole research team before the official reporting. The activity aimed at fostering exchange among the team members about their TD progress and growing understanding, reflecting challenges and opportunities as well as identifying strategies to improve future TD work.

The capacity building activities started with the 5-days training course in the proposal elaboration stage (stage 3) and were continued during the research project implementation (stages 5 and 8). The 5-days training course was offered to all 98 principal investigators (PIs) of the shortlisted pre-proposals and aimed at enhancing the early career scientists' capacities to develop TDR proposals and implement TDR projects. It was designed as a modular event whereby the participants received tailored training inputs on what TDR is and how to do TDR, presented their pre-proposals and worked on their full proposals integrating the training inputs and feedbacks. After the projects started, the programme supported them through further capacity building activities aiming to enhance their skills in implementing TDR. The activities included training modules at the annual research fora (e.g. on knowledge integration, science-policy interactions, and academic writing), a coaching workshop aiming to support the projects in enhancing the transformative potential of their research through designing promising theories of change, the above-mentioned self-reflection activities, as well as peer-to-peer exchanges and feedbacks on the project designs and implementation performance.

Benefits and challenges generated by these design features and activities (RQ3): Overall, the grant provision and capacity building efforts were described as the most crucial benefits by the large majority of the interviewed grantees of all three cohorts. The grantees expressed that these enabled them in successfully developing the necessary knowledge and skills for designing and leading TDR projects. Two quotations of grantees of the second and third cohort illustrate this finding[1]:

"The programme has allowed us to develop a deeper understanding of TD research and engage stakeholders in a more meaningful manner. Our experience in leading projects across multiple countries has significantly enriched our expertise."

"Key learnings included: (i) The step-by-step and meticulous process of designing and implementing a TD project, requiring careful attention to co-identifying the research problem, co-implementing the project, and co-learning, adapting, and disseminating research findings. (ii) Working with diverse interests and balancing power dynamics - the TD project has enabled me to pay attention to and recognise the significance of thinking about how to navigate issues of power within complex environments."

Especially the 2-step application process with the TDR training course between the pre- and full proposal and the tailored feedback from programme management and experts (stages 1–4) was perceived as particularly useful because it helped the grantees to better understand TDR (its concepts, principles, and methods), and to strengthen their writing skills for TDR project proposals – competences they did not acquire during their previous higher education training. The following statement of a grantee of the first cohort illustrates this insight:

"I believe that maintaining the two-stage call is essential for the LIRA grant. During the pre-proposal stage, most of us were unfamiliar with TD research. However, the TD training conducted after this stage allowed us to develop our skills in TDR and enabled us to develop proposals that aligned with the programme's requirements."

This aspect was confirmed by the interviewed trainers and programme representatives who also stated that the quality of the proposals improved substantially throughout this process. The training further helped to increase the grantees' confidence in approaching societal actors as they felt better equipped to integrate them into their research projects.

Many grantees also underlined the benefits they received from the capacity building events, which were held at later stages (stages 5 and 8), such as coaching workshops and self-reflection activities. These enabled a deepening of their understanding of what TDR is, broadening of their method knowledge, gaining a more accurate picture of the project progress, and re-evaluating the project work plan. A grantee of the second cohort put it as follows:

"The project coaching workshop proved to be valuable as it provided updated skills that had the potential to enhance project implementation at that specific time. On the other hand, the self-reflection workshop conducted before reporting was beneficial for ensuring proper and detailed reporting and harmonising results among collaborating partners."

Other grantees pointed out the benefits of exchanging with their peers since this provided them with demonstrations of the many ways of doing TDR. When learning about these benefits during the evaluation of the first cohort, the programme extended the target audience of capacity building to further include not only PIs of the second and third cohorts, but also their co-PIs.

The challenges highlighted by the grantees mainly concerned the programme's high expectations regarding scientific and societal impacts against the background of available time, staff resources and budget. Grantees of the first cohort mentioned insufficient time between the TDR training and the full-proposal as an important challenge preventing them to fully integrate the learnings from the training, build an interdisciplinary team and co-design the research questions together with societal actors. Moreover, many grantees of all three cohorts stressed that 2-year grants are too short for implementing TDR processes aiming at societal as well as scientific impact in two countries with different socio-cultural contexts and languages.

Some mentioned the time needed for establishment of trust and collaboration with societal actors and cross-country exchanges, others the time needed for the production of TDR academic articles. The following quotation exemplifies how a grantee of the second cohort experienced this challenge:

"The only aspect I found challenging was the funding amount per project. Engaging meaningfully in two different countries (cities in our case), designing societal outcomes for these specific areas, and producing publications within the provided budget proved to be very demanding."

Other grantees experienced difficulties in implementing the research in addition to their ongoing teaching duties or highlighted the institutional bureaucracies and inefficiencies of their home universities, such as accessing funds and transferring funds between different African universities. Grantees expressed this in statements such as:

"We encountered logistical challenges, particularly with the protracted procurement processes at our administering institution and delays in the release of the 2nd tranche of funds. These issues resulted in several problems, including the delayed implementation of project activities, the loss of data due to the unavailability of data logging equipment deployed in participating communities, a decline in motivation among research team members and study community participants. As a consequence, the quality of data collected was negatively affected."

The programme representatives acknowledged these challenges and some members of the scientific advisory committee found that the grantees were overburdened with other-than-research duties such as administration. As the overall programme framing was set, only some of these challenges could be tackled. For example, the programme increased the timespan between the TDR training and the submission of the full-proposals in the second and third calls from 6 to 8–10 weeks. However, the short project duration of 2 years could not be changed. In addition, programme representatives also highlighted the need to include university administrations into capacity building to enable proper backoffice support for scientists of future programmes:

"I believe LIRA 2030 Africa did not anticipate the challenge of providing funding to early career scientists who lack significant influence within their own universities to manage this funding properly. (…) I think there is a need to address this issue in a future project: Training must be provided to universities on how to handle seed money for early career scientists effectively."

An additional identified challenge was the organisation of the review and selection process, namely the lack of experienced TDR reviewers for the proposal evaluation.

Pathway 2: Supporting African early career scientists to pursue a career as TDR researchers. The second identified pathway to foster TDR in Africa (RQ1) is to support African early career scientists to pursue a career as TD researchers. The pathway expects that African-based TDR can only flourish if young TDR scientists can establish themselves in the existing science institutions in the long term. While the first pathway also contributes to career advancement, the programme found that more is needed than TDR funding and TDR capacity building to enable the early career scientist to pursue a career as TD researchers. This is leadership competences, network building, as well as scientific and institutional visibility and recognition. Reciprocally, it is obvious that progress towards these additional goals also positively influences the grantees capacity to lead a TDR project (pathway 1).

To deliver this pathway (RQ2), LIRA decided in stage 1 (programme preparation) to include career advancement of its grantees as an important strategic goal of the programme. As a first measure, the applicants had to demonstrate institutional support and mentorship by a senior researcher, aiming – among others – to guarantee institutional embedment and advice (stage 2). Once the projects started, the programme regularly provided information about career opportunities, such as relevant global events and funding calls. Moreover, LIRA organised leadership trainings focusing on issues like scientific publishing, science communication and (financial) project management as part of the annual three-day research fora (stage 8). These fora also fostered scientific exchange, network building and the building of a community of practice with peers and experienced African TDR researchers, facilitators and trainers (South-South collaboration) (stage 7). To deepen these collaborations and enabling joint publishing, the programme reallocated funds to special cross-project collaborative grants in the second part of the programme (160,000 Euro for eight projects). In addition, the programme supported the grantees in gaining visibility and recognition in the scientific community by providing opportunities for external communication via the development of blogs and videos. Furthermore, the programme appointed several grantees for international scientific conferences, working groups and inter-governmental policy events (e.g. at the United Nations Science, Technology and Innovation Forum, the Intergovernmental Panel on Climate Change in Cities, and the High-level Political Forum on Sustainable Development) (stage 9).

The provided career building opportunities generated through the activities of the first and second pathway (RQ3) were described as helpful by the interviewed grantees. They stated to feel confident in continuing to use TDR approaches in their future research and to pursue careers as TD researchers. A grantee of the first cohort expressed this as follows:

"The LIRA project has moulded and developed me into a more mature researcher, fully prepared to face and overcome the research challenges that may arise in future projects. Additionally, it has significantly boosted my

career, providing me with academic credibility in my university and societal recognition for my efforts in building more resilient communities."

The benefits highlighted by grantees of all three cohorts included: (a) Acquired knowledge and skills for doing TDR; (b) increased leadership record to independently implement own research projects; (c) improved self-confidence and recognition within their research community and at their home universities due to their enhanced research portfolio; (d) enhanced participation in local, national and international policy processes and stronger recognition by decision-makers and community members; and (e) strengthened international networks with peers and high-level actors from Africa and beyond. In the words of two grantees of the first and second cohort, this sounds like this:

"I am now part of an incredibly strong network of African TD researchers, which is invaluable."

"I received sponsorships to attend and present at the 2018 United Nations Science Technology and Innovation Stakeholders Forum in New York. (…) Exposure to high level policy processes at the international level enabled me to develop very useful networks and contacts in research and policy."

Many interviewees trusted that their future career path will be facilitated by these benefits, namely finding potential collaborators, acquiring new research projects, and joining forces for change. Some of the interviewees reported about immediate career advancements (e.g. internal promotions to associate professors or fix-term contracts) or enhanced external recognition by policy makers. Others were able to acquire additional funding to continue their research or dissemination activities after the programme ended. The following two quotations exemplify these findings:

"Very importantly, drawing on the insights and knowledge I have gained through the LIRA project, I have been able to write much better integrated TD research proposals, and two of such have been funded."

"Before my acquisition of the LIRA 2030 Africa grant, I was just a senior instructor in my department, which was a contract position valid for 2 years. Upon my acquisition of the grant, firstly, I was given the position of an assistant coordinator (…) and later, I was fully recruited in the university as an Assistant Lecturer, pending promotion to the grade of a Lecturer, all thanks to the LIRA project."

However, while increasing their competences, networks and scientific recognition, pursuing a career as TD researcher and acquiring additional research funding continued to be challenging for the grantees. Several grantees reported the challenge of becoming independent TDR scientists at their home institutions and that the intended institutional mentorship by senior researchers was partly hampered due to their limited involvement and experience with TDR. Two grantees quit their academic careers altogether to work for civil society organisations.

Overall, the interviewed members of the scientific advisory committee were very satisfied with the achieved career advancement of the grantees and their presence at high-level science and policy processes, in particular against the background of the available funding. One member even noted:

"I think the fact that some of the grantees have had very useful intellectual and global platforms for them is phenomenal. (…) I don't think all of the achievements are visible yet. Often, strong research relationships can take

a decade or more to mature fully. People go back and work with those they met years ago, and this long-term impact may not be immediately apparent."

However, another member also criticised the underfunded and opportunity driven approach, which was based on the engagement of individuals rather than a systematic career building process, as well as the limited institutionalisation of measures, namely regarding the long-term existence of the established network.

"One of the things I think LIRA should be proud of is creating a new layer of capacity building that moves away from the paternalistic approach of bringing knowledge from the North. I believe the networking of sustainability scientists is one of the most outstanding outcomes of the LIRA programme in Africa. It has paved the way and provided a model for capacity-building programmes. (…) However, the institutional connection was just an opportunistic connection, not a structural one that helps continue the activities beyond the LIRA programme. We have to question that model and that particular side of institutional collaboration."

The programme representatives concluded that in order to better address these issues in future research programmes more human resources and financial capacity need to be mobilised and the grantees home institutions as well as existing African networks should be more strongly integrated.

Pathway 3: Enhancing context conditions within which TDR researchers operate. The third identified pathway to foster TDR in Africa is the enhancement of context conditions for doing TDR. It is about the context TDR scientists are embedded and reaches beyond the focus on the individual scientists (RQ1). The pathway assumes that existing context conditions are often unfavourable for TDR (e.g. lacking recognition, career incentives and funding opportunities), and that universities and funding agencies need to better acknowledge the characteristics of TDR to enable African early career scientists pursuing a career as TDR scientists.

Aiming to create an enabling environment for TDR (RQ2), the programme fostered synthesis and communication of the project's experiences with doing TDR in Africa, promotion of TDR capacity building at research institutions, and engagement with global research funders to mobilise further funding for African research on sustainable development (stages 7 and 9).

Synthesis and communication activities aimed to showcase the experiences of African TDR initiatives. Furthermore, they served to demonstrate the value of TDR in these specific contexts and, importantly, to encourage other researchers and institutional actors to implement and support TDR efforts in Africa. It included the following activities (stage 7): Grantees of eight projects jointly wrote a report about their experiences in doing TDR (ISC, 2020), the learning study out of which this paper emerged was established (see method section), synthesis of learnings across LIRA projects through collaborative grants that resulted in eight articles, and programme representatives are involved in the development of guidelines for conducting TDR training courses and training for trainers initiatives that integrate African perspectives. Subsequently, the projects' insights and the related roles of TDR were communicated via videos, blogs and reports (stage 9).

To promote TDR capacity building in African research institutions, the programme invited representatives of various African Universities and National Academies of Sciences to attend the TDR training courses and to learn how TDR can be

integrated in their curricula. In 2019, the ISC launched the initiative "Global Forum of Funders" under the LIRA framework. This forum regularly brought science funders, representing national research funding agencies, international development aid agencies, and private foundations together to explore collaborative actions for maximising the impact of science and science funding in achieving the 2030 Agenda for Sustainable Development, particularly in the Global South. To date, two Forums took place one in 2019 and one in 2021.

Regarding benefits of these programme activities (RQ3), the interviewed programme representatives concluded that they see a certain increase in awareness and recognition of TDR in the involved African and international science institutions, and among science funders. They derived this conclusion from the strong interest for the programme's knowledge products, which featured the value of TDR for urban development in Africa, as well as the work at the Global Forum of Funders. Several grantees also described how their home universities have become increasingly interested and open for TDR. They attributed theses changes in attitudes to the implementation of their projects and the involved TDR capacity building activities including the involvement of master students and non-academic stakeholders. Some grantees also indicated that the growing responsiveness to ongoing social challenges at their institutions led to an increased acknowledgement of the importance of TDR in tackling those challenges.

However, our findings also demonstrate how institutional policies within many science institutions still remain partly unfavourable for TDR.

The programme representatives recognised that this pathway focusing on the context of TDR requires long-term strategic and collaborative action from scientists, universities, science funders, science policy makers and governments, far beyond what can be provided within the framework of a single programme. Against this background, they emphasised the programme's engagement with other science funders at the Global Forum of Funders, which is perceived as an important first step towards upscaling collective efforts that enables science funders to foster TDR more effectively. Moreover, more explicit and formal commitment towards this pathway would be needed, including substantially more resources and time dedicated to interactions with African science institutions and other existing networks and programmes (Western-African, African-African) for creating strategic, long-term institutionalisation of the emerging changes.

Discussion and concluding remarks

This paper aimed to contribute to evidence building on how research funding programmes can foster TDR for advancing sustainable development in Africa. The LIRA programme served as an empirical case, as it is the first funding programme supporting TDR in Africa on a continental scale.

Studying the programme, we identified three interrelating pathways to impact and related activities through which the programme aimed to foster TDR: a) Enabling African early career scientists to undertake high-quality TDR projects; b) enabling African early career scientists to pursue a career as TDR researchers; and c) enhancing the context conditions for doing TDR in Africa.

Programme activities related to each pathway came along with manifold benefits, such as learnings related to TDR, scientific recognition, visibility of African researchers in international debates, and enhanced collaboration across funders. Overall, the programme's contributions to TDR capacity building might be most innovative, going far beyond reported activities of other funding programmes (e.g. Schneider et al. 2019). Capacity

building started with a training course during the application process and continued with additional training and learning activities, such as the coaching workshop or the self-reflection activities during research implementation. These enabled the grantees to deepen their understanding, reflect on their own processes, learn from the experiences of other researchers and continuously fine-tune their TDR approaches. To our knowledge, no standardised capacity building curricula for TDR funding programmes exist to date. Hence, the experiences gained in the LIRA programme can serve to contribute to the development of such a curriculum. From the broad range of benefits and learnings mentioned by the grantees, we conclude that it is important to cover the whole "value chain" of TDR but with a clear focus on actionable knowledge, learning by doing and self-reflection (theory, methods, case studies, know-how). Moreover, it is important to adequately phase the learning activities starting with inputs that are needed to design high quality proposals (e.g. methods for co-designing research aims), followed by instructions for operationalization of research (e.g. stakeholder engagement methods) and eventually providing insights for bringing results to fruition.

Challenges were also substantial and – not surprisingly - increased from the first to the third pathway as the impact goals became more ambitious and systemic. Nevertheless, we conclude that the very combination of the three pathways is required for fostering African leadership in TDR in the long-term: Taken that many applicants and later grantees had only limited experiences in TDR, the combination of research funding with capacity building and career development proved to be key (first and second pathways to impact). Moreover, several experienced challenges were related to unfavourable context conditions, such as limited institutional awareness and recognition of TDR approaches, as well as limited opportunities for long-term TD career development and for acquisition of additional funding. All of these challenges underline the importance of the third pathway to impact. However, truly enhancing this third pathway would require more dedicated focus, activities and resources than the programme could provide.

These findings correspond with studies about African science systems, which highlight that improvement of research capacity in Africa requires not only capacity building of individual researchers, but also institution-building interventions (Atindehou et al. 2019; Mouton, 2018; Mouton and Blanckenberg, 2018). Moreover, it corresponds with recent studies stressing that funders can and should support and incentivize TDR through various means ranging from provision of grants, capacity building to collaborations among funders (Arnott et al. 2020; OECD, 2020).

The three pathways specifically targeted African early career scientists taking into account their specific contextual conditions and needs. Nonetheless, we think that the pathways might also be suitable for other target groups, both in the Global South and North, as competences in TDR are still not part of most university curricula, and context conditions are notoriously unfavourable for TDR careers (Jaeger-Erben et al. 2018; OECD, 2020).

The study also confirms previous insights about TDR funding programmes stating that such programmes must plan their activities throughout the programme stages to adequately support whatever pathway they have chosen to pursue (Defila et al. 2006; Lyall et al. 2013; Matso and Becker, 2014; Schneider et al. 2019). Namely, these activities involve the programme development and application process (e.g. sufficient time for team building and proposal co-design, suitable review criteria and reviewers with TDR competences, as well as provision of adequate funding volumes covering co-production activities over several years), project support (e.g. sharing of information, capacity building, networking and career building opportunities), monitoring and

evaluation (e.g. enabling self-reflection about TDR progress), and external communication (e.g. supporting targeted communication, enabling participation at conferences, organising collaborative events). While activities at all programme stages are important, we found that those at the beginning need particular attention as they not only determine the framework but also develop the skills required for the later stages. While this finding on setting the scene is broadly recognised for issues like solicitation criteria (Arnott et al. 2020; Woelert and Millar, 2013), we could show that it is also true for engagement with societal actors and capacity building. In this respect, we would like to highlight the two-step application process with time allocated for co-design and the TDR training course taking place during this process, which was highly valued by all participants and considerably helped to secure initial engagement of project partners and improved the quality of the proposals and later research.

In conclusion, the results of this study highlight the importance of implementing and critically reflecting such novel funding programmes for strengthening the science-society-policy interactions in Africa and tackling science inequalities between the Global North and South. Taking the learning of this study into account, the programme can be regarded as a prototype for future funding programmes aiming to foster TDR research, TDR capacity building and TDR leadership competences (first and second pathways to impact). More exploration and research is needed to identify suitable programme activities for transforming the context conditions of TDR as outlined in the third pathway to impact.

Last but not least, the challenging context of the endeavour suggests that implementation of such novel programmes are embedded in systematic learning processes which allow to learn from early experiences and continuously implement improvements.

Data availability
Different datasets were generated and/or used in this study. Data of the final survey is accessible on request via DOI 10.5281/zenodo.8238101. The analysed programme documents and the transcripts of the interviews are not publicly available due to confidentiality reasons (it contains information, which enables to identify individuals).

Note
1 All direct quotations are language-edited for clarity, as the majority of interviewees are non-native English speakers.

References
African Union Commission (2015) Agenda 2063 - The Africa We Want
Arnott JC, Kirchhoff CJ, Meyer RM, Meadow AM et al. (2020) Sponsoring actionable science: what public science funders can do to advance sustainability and the social contract for science. Curr Opin Environ Sustain 42:38–44
Arnott JC, Neuenfeldt RJ, Lemos MC (2020) Co-producing science for sustainability: can funding change knowledge use? Glob Environ Change 60:1–12
Atindehou M, Adéoti K, Loko LEY Beulé T et al. (2019) MooSciTIC: training of trainers in West African research and higher education. PLoS Biol 17/6:1–11
Barth M, Bruhn A, Lam DP, Bergmann M et al. (2020) Capacity building for transformational leadership and transdisciplinarity. GAIA - Ecol Perspect Sci Soc 29(3):195–7
Beaudry C, Mouton J, Prozesky H (eds) (2018) The Next Generation of Scientists in Africa. African Minds, Cape Town, South Africa (ZA)
Belcher BM, Rasmussen KE, Kemshaw MR, Zornes DA (2016) Defining and assessing research quality in a transdisciplinary context. Res Eval 25(1):1–17
Biermann F (2002) Insitiutions for scientific advice: global environemntal assessments and their influence in developing countries. Glob Governance 8(2):195–219

Bromham L, Dinnage R, Hua X (2016) Interdisciplinary research has consistently lower funding success. Nature 534(7609):684–7
Burawoy M (1998) The extended case method. Sociol Theory 16(1):4–33
Chataway J, Dobson C, Daniels C, Byrne R et al. (2019) Science granting councils in Sub-Saharan Africa: trends and tensions. Sci Public Policy 46(4):620–31
Culwick C, Patel Z (2017) United and divided responses to complex urban issues: insights on the value of a transdisciplinary approach to flooding risk. Area 49(1):43–51
Dedeurwaerdere T (2013) Transdisciplinary sustainability science at higher education institutions: science policy tools for incremental institutional change. Sustainability 5(9):3783–801
Defila R, Di Giulio A, Scheuermann M (2006) For-schungsverbundmanagement: Handbuch für die Gestaltung inter-und transdisziplinärer Projekte: vdf Hochschulverlag AG, Zürich
European Commission (2020) Joint Communication to the European Parliament and the Council: Towards a comprehensive Strategy with Africa. Brussels, Belgium
Fazey I, Schäpke N, Caniglia G, Hodgson A et al. (2020) Transforming knowledge systems for life on Earth: Visions of future systems and how to get there. Energy Res Soc Sci 70:101724
Flick U (2005) Qualitative Sozialforschung. Eine Einführung. Rowohlt Taschenbuch Verlag, Reinbek bei Hamburg
Harle, J. (2016) Who Drives Research In Developing Countries?, https://blog.inasp.info/drives-research-developing-countries/ accessed 12 Aug 2021
Hirsch Hadorn G, Bradley D, Pohl C, Rist S et al. (2006) Implications of transdisciplinarity for sustainability research. Ecol Econ 60(1):119–28
Hoffmann S, Pohl C, Hering JG (2017) Exploring transdisciplinary integration within a large research program: empirical lessons from four thematic synthesis processes. Res Policy 46(3):678–92
Huutoniemi, K. (2014) Introduction: sustainability, transdisciplinarity and the complexity of knowing. Transdisciplinary Sustainability Studies, https://www.taylorfrancis.com/ accessed 11 Mar 2020
International Science Council (ISC) (2020) Advancing the 2030 Agenda in African cities through knowledge co-production. Paris
Jaeger-Erben M, Kramm J, Sonnberger M, Völker C et al. (2018) Building capacities for transdisciplinary research: challenges and recommendations for early-career researchers. GAIA - Ecol Perspect Sci Soc 27(4):379–86
Jahn T, Bergmann M, Keil F (2012) Transdisciplinarity: Between mainstreaming and marginalization. Ecol Econ 79:1–10
Kinyanjui, S. and Fonn, S. (2020) Africa's research capacity is growing. That's good news for pandemic response efforts, https://www.wits.ac.za/news/latest-news/opinion/2020/2020-07/africas-research-capacity-is-growing-thats-good-news-for-pandemic-response-efforts.html accessed 17 Mar 2021
Kläy A, Zimmermann AB, Schneider F (2015) Rethinking science for sustainable development: Reflexive interaction for a paradigm transformation. Futures 65:72–85
Kozma C, Medina CC, Costas R (2018) Research funding landscapes in Africa. In: Beaudry C, Mouton J, Prozesky H (eds) The Next Generation of Scientists in Africa. African Minds, Cape Town, South Africa (ZA)
Kueffer C, Underwood E, Hirsch Hadorn G, Holderegger R et al. (2012) Enabling effective problem-oriented research for sustainable development. Ecol Soc 17(4):8
Lang DJ, Wiek A, Bergmann M, Stauffacher M et al. (2012) Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain Sci 21:25–43
Llopis JC, Diebold CL, Schneider F, Harimalala PC et al. (2020) Capabilities Under Telecoupling: Human Well-Being Between Cash Crops and Protected Areas in North-Eastern Madagascar. Front Sustain Food Syst 3:1–20
Lyall C, Bruce A, Marsden W, Meagher L (2013) The role of funding agencies in creating interdisciplinary knowledge. Sci Publ Policy 40(1):62–71
Maas, B., Pakeman, R. J., Godet, L. and Smith, L. et al. (2021) Women and Global South strikingly underrepresented among top-publishing ecologists. Conserv Lett 14:e12797
Maassen, P. (2020) Developing equal, mutually beneficial partnerships with African universities. Recommendations for a new European collaboration strategy
Mach KJ, Lemos MC, Meadow AM, Wyborn C et al. (2020) Actionable knowledge and the art of engagement. Curr Opin Environ Sustain 42:30–7
Mansilla VB (2006) Assessing expert interdisciplinary work at the frontier: an empirical exploration. Res Eval 15(1):17–29
Matso KE, Becker ML (2014) What can funders do to better link science with decisions? Case studies of coastal communities and climate change. Environ Manag 54(6):1356–71
Messerli P, Kim EM, Lutz W, Moatti J-P et al. (2019) Expansion of sustainability science needed for the SDGs. Nat Sustain 2(10):892–4
Mouton J (2018) African science: A diagnosis. In: Beaudry C, Mouton J, Prozesky H (eds) The Next Generation of Scientists in Africa. African Minds, Cape Town, South Africa (ZA)
Mouton J, Blanckenberg J (2018) African science: A bibliometric analysis. In: Beaudry C, Mouton J, Prozesky H (eds) The Next Generation of Scientists in Africa. African Minds, Cape Town, South Africa (ZA)

Newig J, Jahn S, Lang DJ, Kahle J et al. (2019) Linking modes of research to their scientific and societal outcomes. Evidence from 81 sustainability-oriented research projects. Environ Sci Policy 101:147–55

Ngongalah L, Rawlings NN, Wepngong E, Musisi J et al. (2019) Tackling the research capacity challenge in Africa: An overview of African-led approaches to strengthen research capacity, bioRxiv 518498

Nowotny H, Gibbons M, Scott P (2001) Re-thinking science: knowledge and the public in an age of uncertainty. Polity, Cambridge

Nuñez MA, Barlow J, Cadotte M, Lucas K et al. (2019) Assessing the uneven global distribution of readership, submissions and publications in applied ecology: Obvious problems without obvious solutions. Journal of Applied Ecology 56(1):4–9

OECD (2020) Addressing societal challenges using transdisciplinary research

Patel Z (2019) The triumphs and trials of transdisciplinary research: reflections on the un-disciplining of disciplines, https://council.science/current/blog/the-triumphs-and-trials-of-transdisciplinary-research-reflections-on-the-un-disciplining-of-disciplines/ accessed 12 Aug 2021

Patel Z, Schneider F, Paulavets K (2022) Linking Local Projects With Global Processes: Learning From Transdisciplinary Collaborations in African Cities. In: Frontiers in Sustainable Cities, 4, S. 1–14

Roux DJ, Stirzaker RJ, Breen CM, Lefroy EC et al. (2010) Framework for participative reflection on the accomplishment of transdisciplinary research programs. Environ Sci Policy 13(8):733–41

Schneider F, Buser T (2018) Promising degrees of stakeholder interaction in research for sustainable development. Sustain Sci 13(1):129–42

Schneider F, Buser T, Keller R, Tribaldos T et al. (2019) Research funding programmes aiming for societal transformations: ten key stages. Sci Publ Policy 46(3):463–78

Schneider F, Kläy A, Zimmermann AB, Buser T et al. (2019) How can science support the 2030 Agenda for Sustainable Development? Four tasks to tackle the normative dimension of sustainability. Sustain Sci 14(6):1593–604

Schneidewind, U. (2009) Nachhaltige Wissenschaft. Marburg, Germany: Metropolis

Schön DA (1983) The reflective practitioner: How professionals think in action. Basic Books, New York

Sheikheldin GH, Mohamed AA (2021) Skills for Science Systems in Africa: The Case of 'Brain Drain. In: Hanlin R, Tigabu AD, Sheikheldin G (eds) Building Science Systems in Africa: Conceptual Foundations and Empirical Considerations. Mkuki na Nyota Publishers Ltd, African Centre for Technology Studies (ACTS), Dar es Salaam, Nairobi

Stauffacher M, Flüeler T, Krütli P, Scholz R (2008) Analytic and dynamic approach to collaboration: a transdisciplinary case study on sustainable landscape development in a swiss prealpine region. Syst Pract Action Res 21(6):409–22

UN GSDR (2019) United Nations Global Sustainable Development Report 2019: The Future is Now – Science for Achieving Sustainable Development. New York

van Breda J, Musango J, Brent A (2016) Undertaking individual transdisciplinary PhD research for sustainable development. Int J Sustain Higher Educ 17(2):150–66

van Breda J, Swilling M (2019) The guiding logics and principles for designing emergent transdisciplinary research processes: learning experiences and reflections from a transdisciplinary urban case study in Enkanini informal settlement, South Africa. Sustain Sci 14(3):823–41

van Jaarsveldt LC, de Vries MS, Kroukamp HJ (2019) South African students call to decolonize science: Implications for international standards, curriculum development and Public Administration education. Teach Public Admin 37(1):12–30

Woelert P, Millar V (2013) The 'paradox of interdisciplinarity' in Australian research governance. Higher Educ 66(6):755–67

Acknowledgements

Author contributions

The authors confirm their contribution to the paper as follows: Conceptualisation: FS, ZP, KP, TB and JK; methodology and writing of original draft: FS; data curation: KP and SB; formal analysis and visualisation: FS and SB; investigation: All, writing – review and editing: All. All authors reviewed the results and approved the final version of the paper.

Funding

Open Access funding enabled and organized by Projekt DEAL.

Competing interests

The two co-authors representing the programme were employed by ISC on the funding line mentioned in the acknowledgements (the co-production approach among them and the independent researchers is described in the method section of the article).

Ethical approval

The applied method followed Swiss regulations. Neither approval from an ethics committee nor written consent to participate is required according to Swiss regulations. We certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all participants.

Additional information

Correspondence and requests for materials should be addressed to Flurina Schneider.

Reprints and permission information is available at http://www.nature.com/reprints

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.