Undertaking individual transdisciplinary PhD research for sustainable development: Case studies from South Africa

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Structured abstract

Purpose: This paper aims at improving the understanding of individual transdisciplinary PhD research in a developing country context, focusing on three individual PhD case studies in South Africa.

Design/methodology/approach: The multiple-case method was used, and three completed transdisciplinary PhD research efforts undertaken at Stellenbosch University were selected. They were coordinated through the TsamaHub[1], an inter-faculty platform at the University which organises educational modules for transdisciplinary research. Using actual research experiences and reflections of the three individual PhDs, the paper evaluates their work in terms of ontological, epistemological, methodological and methodical/methods aspects.

Findings: The central **c**hallenge to individual PhD researchers is engagement with non-academic actors to enable joint problem formulation, analysis and transformation. To overcome this, the paper suggests that developing individual epistemic relationships to build 'transdisciplinary epistemic communities' should be considered for inclusion as an intentional aspect of transdisciplinary research design.

Research limitations/implications: 'Transdisciplinary epistemic communities' is still a concept in its infancy and needs more work before it may be theoretically and practically useful.

Practical implications: Continuously guiding the individual transdisciplinary research process in a reflexive, recursive, transparent and equal manner is absolutely critical, because transdisciplinary research cannot be done successfully if dominated by overly methods-driven approaches.

Originality/value: The discourse around transdisciplinary methodology has major implications for the design of individual PhD research. The paper provides recommendations to enhance the theory and practice of individual transdisciplinary PhD research.

Key words: transdisciplinary research; hybrid ontology; relational epistemology; integrative methodology; transdisciplinary epistemic communities; boundary objects.

Article type: Case study.

[1] http://www.tsama.org.za/

Introduction

The planetary consequences of living in the Anthropocene (Crutzen, 2002) (Glaser et al., 2012) (Latour, 2013) (Steffen et al., 2007) have major implications for academia in society today. When dealing with global problems such as climate change, poverty, food security, water, energy, waste, soil, biodiversity, and others, it is no longer appropriate to produce knowledge *for* society only. What has become equally important and urgent is the co-production of knowledge *with* society. The major reason for this is that in the Anthropocene we are dealing with unprecedented complex sustainability crises[2]. They are complex because they are truly planetary-level problems which are being produced by *both* nature and society, with long-term consequences for both. Consequently, these 'hybrid' problems can no longer be approached in terms of the two-world theory of treating the 'natural' and 'social' as two fundamentally different and unconnected realities, which can only be worked on separately by the natural and social sciences in isolation of society. At best, these mono-disciplinary approaches will only produce partial solutions. What are needed today are fundamentally different approaches capable of *co-generating* integrated solutions *between* science and society.

Transdisciplinarity (TD) has emerged over the last two decades not as a 'new' science *per se*, but rather as a methodological response to the need for a new mode of doing science *with* society. When doing science in a *transdisciplinary way*, it means having to work *with* and negotiate the practical and theoretical interests of society and science *simultaneously*. It also means developing and using the collaborative research practices necessary for achieving two vitally important objectives: co-producing practical knowledge that is oriented towards the strategic goals of society (Hessels and Van Lente, 2008), and co-producing innovative theoretical knowledge for providing us with new insights and understanding of the complex problems we are facing (Jahn, 2008) (Hadorn and Pohl, 2008) (Scholz, 2011) (Glaser et al., 2012) (Bergmann et al., 2013). TD is therefore not an exercise purely in instrumental reasoning and practice, and cannot be reduced to a problem-solving tool or method *only*. This is because knowledge co-production always involves developing *new* theories, problem statements, research questions, integrative research methods, and more. This means that we can never be satisfied with merely explaining (Erklärung) and understanding (Verstehen) the complex nature of the world, without also discovering ways and means of changing (Verändern) the world; or rather changing *our actions in the world*.

By bringing society into the research process, to help co-direct and guide the latter (Collins and Evans, 2002), is another way of saying that *context* matters hugely in transdisciplinary research. Mindful of the fact that our own transdisciplinary research is embedded in the African context, we are fully aware of the unique sustainability and developmental challenges we are facing, which include, inter alia, extreme poverty and inequality, dependence on rapidly degrading eco-system services, energy, water and food insecurities, and the looming threats triggered by climate change. There is not just one big, dominating problem, but rather many interconnected and interdependent problems, which are unique in their scale, intensity and social and environmental impact when compared to those of the developed North.

[2] These global sustainability crises are being referred to as the 'polycrisis' in the Ontology section below.

In 2010, the first transdisciplinary doctoral programme in sustainability in SA was introduced at SU (Muhar et al., 2013). Key events of the doctoral programme are the annual TD Summer and Winter Schools, as well as the two-weekly doctoral seminars aimed at developing a shared theoretical framework and understanding of the transdisciplinary approach amongst the participating doctoral students. In this regard, the Summer and Winter Schools consist of a number of core (non-credit bearing) one-week modules in: (i) sustainability or sustainable development, (ii) complexity theory and systems thinking, (iii) and transdisciplinary theory and methodology. All of these activities are coordinated and managed by a specially created inter-faculty research institution or platform at SU, known as the TsamaHub[3]. During 2012 and 2013 the first three PhDs of the 2010 cohort successfully completed the transdisciplinary doctoral programme in their respective home faculties and departments. A common feature of these three PhDs is that all of them did their research *individually*, and did not participate in any larger transdisciplinary research projects or case studies. The literature on doing such individual transdisciplinary research work in a developing world context is non-existing.

Objectives of the paper

This paper thus aims to fill this gap by providing insight into the transdisciplinary research process to address issues of sustainability. Specifically, the paper investigates the process of individual transdisciplinary PhD research efforts, rather than that of transdisciplinary research teams that have been investigated in the South African context (Brent and Swilling, 2013). Given the practical constraints – such as time, resources, logistics, etc. – that individual transdisciplinary PhD researchers may be faced with, the implication is that individual transdisciplinary research efforts cannot necessarily tackle the abovementioned societal challenges in the same way as large transdisciplinary research teams (Stokols et al., 2008). Following from this, some of the relevant questions investigated are: what type of complex societal problems can be tackled in an individual transdisciplinary research effort; how does the individual transdisciplinary researcher go about doing this type of research; and, what types of outcomes can be expected? The paper further evaluates the three individual PhD research cases by looking at the ontological, epistemological, methodological and methodical or methods aspects. Finally, the paper provides recommendations to enhance the theory and practice of individual transdisciplinary PhD research.

Methodological approach of the paper

The multiple-case method advocated by, amongst others, Yin (Yin, 2009), Gerring (Gerring, 2006) and Krohn (Krohn, 2010), was used in this paper. Three completed transdisciplinary PhD research efforts undertaken at SU were selected, that were diverse enough to satisfy the requirements of the case study research methodology, addressing different real-world sustainability challenges in an Africa context.

Many different terms have been used in the literature[4] to describe the complex nature of sustainability challenges. However, when considering the specific challenges that the PhD

[3] Refer to: www.tsama.org.za for more information on the TsamaHub.

[4] These are elaborated in the Ontology section below.

researchers focussed on, we prefer to use 'boundary objects' (Becker, 2012) (Star and Griesemer, 1989) (Star, 2010) as the collective term rather than the restrictive 'unit(s) of analysis'. Although the latter has been widely used in the research literature, it has been used in a way that can only conceive of the object(s) of study as something which can be *either* 'natural' *or* 'social', but not *both* at the same time. This is too binary, reductionist and mutually exclusive for our purposes, and also focusses too narrowly on the *analysis* of problems with little or no attention given to the crucial issue of *problem transformation*. We therefore prefer the term 'boundary objects' because it not only refers to the anthropogenic nature of objects that are *both* natural *and* social, but also, in their causes and effects, produce real-world problems that warrant practical, integrated and innovative solutions.

Case study 1: Exploring food security of subsistence farmers at the micro-household level[5]

The first case study focussed on the issue of food security of subsistence farmers at the micro-household level, specifically in the rural areas of the Kwa-Zulu Natal (KZN) region of South Africa (SA). The solution explored in this study involves a possible radical change in farming practices that will involve growing different crop varieties, including African leafy vegetables locally known as 'imfino' or 'morogo'. Rural households and subsistence farmers are familiar with these crop varieties. However, they are still not generally accepted due to strong negative perceptions. Addressing food security in the African context via these so-called 'wild' vegetables is a good example of working with a boundary object situated at the interface of the 'natural' and the 'social'. It is also a good example of sustainable development, where social, ecological and economic aspects are integrated into a solution that benefits all three aspects. The solution in this case study therefore warranted a transdisciplinary response of linking soil science, agronomy, human nutrition, economics and anthropology with the experiential knowledge of the subsistence farmers.

Case study 2: Analysing the sustainability of renewable energy technologies[6]

The second case study focussed on how improving of technology assessment practices can bring about systems change in energy production and usage in South Africa. Bio-diesel, a renewable energy, in which the feedstock was to be produced in the poor Eastern Cape Province of South Africa, was chosen as the boundary object, which may address the social issues of rural development, poverty reduction and unemployment, whilst simultaneously addressing technological and energy needs – without over-shooting the carrying capacity of the natural environment. This effort differs to the first, but shares with it the qualities of a sustainable development solution in which the environmental issues of climate change and resource scarcity, and societal-economic issues of poverty and unemployment, are tackled together.

Case study 3: Exploring transitions through meaningful nature experiences[7]

[5] For a copy of this PhD thesis, refer to: http://hdl.handle.net/10019.1/87030

[6] For a copy of this PhD thesis, refer to: http://hdl.handle.net/10019.1/18149

[7] For a copy of this PhD thesis, refer to: http://hdl.handle.net/10019.1/86290

The third transdisciplinary research effort is fundamentally different to the first two case studies, both in its context, and, very importantly, in its 'boundary object' type. The central question being explored in this case study is whether our 'disconnect' from nature can somehow be 'reconnected' via certain meaningful nature experiences (MNEs). As the human disconnect from nature is seen by many to be the root cause of environmental degradation, our reconnection could accelerate sustainable development. While the boundary objects in the first two cases were *material things*, such as plants and bio-diesel, the boundary object in the third case was non-material; namely our meaningful experiences of nature. Therefore, boundary objects no longer have to be imagined strictly in terms of physical things or objects only, but also in relational terms, where the subject-object relationship is inseparable.

Insights from the three case studies

Unlike in the developed world with its much higher levels of social and educational equality, transdisciplinary researchers in a developing world context need to learn how to navigate their way through a very different set of social conditions. Learning to do this in a transdisciplinary way comes with its own unique challenges because the social conditions are not always conducive for participation in collective, multi-stakeholder type of transdisciplinary case studies where solution-oriented knowledge of these problems can be co-produced between well-resourced and organised stakeholders. In this situation, the strategic research design question becomes: with whom, in what locales, in what type of interactive processes can individual transdisciplinary research efforts take place, and with what sort of outcome? If it is accepted that boundary object problems can only be tackled collaboratively between members of science and society, what then are the options and research strategies available to individual transdisciplinary researchers to construct an individual interactive research process capable of finding practical solutions to real-world problems, as well as contributing to the theoretical interests of the individual researchers? Indeed, there can be multiple starting points to individual transdisciplinary research processes. However, the participation of all three of our transdisciplinary researchers in the two key programmatic events of the transdisciplinary doctoral programme (Muhar et al., 2013) played a particularly important role in learning how to start and manage the challenging relational aspects of undertaking individual transdisciplinary research. In this regard, two broad insights emerged from the experiences of our three researchers.

Firstly, all three of the researchers confirmed that their participation in the activities of the doctoral programme played a significant role in initiating the process of theoretical problem definition and research question formulation. Rather than entering the research process working with 'static' issues with 'fixed' problem statements, research questions and 'pre-determined' methods, the researchers were continuously challenged with *changes* in the way the issues were approached and conceptualised, depending on *who* and *what* disciplines were participating in the TsamaHub doctoral seminars. Although these insights were initially developed mainly in an interdisciplinary environment of the TsamaHub summer schools and doctoral seminars, the theoretical practice of learning how to formulate and reformulate guiding problem statements and research questions, as well as being flexible on what integrative methods might be appropriate when engaging their social actors in future, certainly played a key role in preparing the researchers conceptually.

Secondly, learning how to work with guiding problem statements and research questions around changing issues developed into a very important strategic sense of how to go about building epistemic relationships with the individual social actors they had identified. Realising early on that it would not be feasible to set up a collective, multi-stakeholder type of transdisciplinary case study, the three researchers proceeded to develop and pursue very different research strategies of working with and building informal individual epistemic relationships with the social actors immediately available to them. Through these relationships they were able to create the necessary opportunities and learning spaces to conduct their individual research efforts. This strategy produced some positive unintended consequences: a transformation of these epistemic relationships into socio-epistemic relationships that lasted beyond their research. The significance of this is further elaborated under the Outcomes section.

What follows in the next four sections is the ontological, epistemological, methodological and methodical or methods aspects of the three individual transdisciplinary research cases.

Hybrid transdisciplinary ontology

Ontology is our systematic inquiry into and theory of the nature of 'reality'. Today we are living in a 'hybrid' world which can no longer be imagined as 'society without nature and nature without society' (Beck, 1992) (Latour, 1993). The term Anthropocene (Crutzen, 2002) (Glaser et al., 2012) (Latour, 2013) (Steffen et al., 2007) depicts the world today as a new planetary era, equivalent in impact to previous geological eras. However, the Anthropocene is characterised by human-produced planetary-scale problems that threaten our existence. This unprecedented epoch has also been described as a 'polycrisis' (Morin and Kern, 1999) in which we are facing not just one big problem, to which all other problems can be reduced; but rather multiple and inextricably interconnected sustainability crises, such as: climate change, poverty, food insecurity, degraded eco-systems, loss of bio-cultural diversity, and others. When dealing with interconnected problems, finding integrated solutions is a complex undertaking. Solutions for one set of problems may very well create new problems, reaffirming why it is not desirable to tackle boundary-object problems from mono-disciplinary approaches only, but with a transdisciplinary approach.

When dealing with boundary object problems at the local or micro level in individual transdisciplinary research, the immediate question that comes to mind is, *can* these complex societal problems be tackled at the micro level? If so, what can we hope to learn? These are important questions, with no simple answers. When read together, the examples of the three case studies provide some clues as to what can be achieved at the ontological level. Firstly, they illustrate the richness of boundary object problems that can be tackled when undertaking individual transdisciplinary research. There is room for exploring a wide variety of boundary objects that may not always be possible in highly structured transdisciplinary case studies where the research agendas and questions are normally negotiated outcomes, or compromises of well-organised science and society stakeholders. Secondly, the lessons learnt from the three cases confirm that it is possible to respond to the non-separability of the subject and object when dealing with the anthropogenic consequences of the polycrisis. In other words, researchers can immerse themselves more 'deeply' into an individual transdisciplinary case. This may result in researchers exploring different angles of the problem to the more structured transdisciplinary efforts with collectively determined research agendas and questions. Thirdly, what can be achieved in individual

transdisciplinary research efforts may not necessarily be actual outcomes or solutions produced at the micro level *per se*, but rather the individual processes that were followed. Individual transdisciplinary cases can achieve 'deeper' levels of learning and understanding (Tosey et al., 2011) of what it takes to work with and build informal, individual epistemic relationships[8] with individual social actors, which may not always be possible in bigger transdisciplinary undertakings. Therefore, when working at the ontological level with complex, multi-faceted problems, it is critically important to value the 'idiographic' component (Krohn, 2010) of what can be learnt from the specificity of individual transdisciplinary cases. In our view, the three areas highlighted above provide evidence of the richness of what can be achieved at the more local or micro levels of transdisciplinary research.

Relational transdisciplinary epistemology

Epistemology is our systematic inquiry into and theory of human knowledge generation and acquisition. A 'transdisciplinary epistemology' should be seen fundamentally as a relational epistemology, as one of *knowledge co-production* (Regeer and Bunders, 2009). The relationality of transdisciplinary knowledge co-production has its epistemological roots in the non-separability of the subject-object relationship. It is taken further throughout the transdisciplinary process where knowledge is always *co-generated;* not only *between* scientific experts from the different social and natural science disciplines (inter- and multi-disciplinarity)*,* but also *between* scientific experts and societal actors. Transdisciplinary knowledge co-production is therefore never a purely individual undertaking, practised strictly within the fixed boundaries of one disciplinary knowledge system. Rather, it is always a dynamic process of knowledge exchange, knowledge integration and knowledge innovation *between* the different disciplines, as well as between disciplines and non-disciplinary or social knowledge systems.

The complexity of boundary object problems implies that finding integrated solutions cannot just come from the co-production of one type of knowledge. At least three different types of knowledge have been identified, namely: systems knowledge, target knowledge, and transformation knowledge (Pohl and Hadorn, 2007) (Hadorn and Pohl, 2008). Systems knowledge deals with the understanding of the context and social conditions *under* which the boundary object problems are being (re)produced, as well as asking *empirical* questions of what 'is' or actually 'constitutes' the 'messiness' or 'unsustainability' of the latter. Target knowledge deals with *normative* questions, about what 'ought to be' a more 'desirable' or 'sustainable' set of social conditions to resolve the problem situation at hand. Transformation knowledge deals with *transitioning* questions; asking what processes and strategies need to be pursued to move *from* the current 'unsustainable' situation *to* a more 'sustainable' one.

These three different types of knowledge are always implicated in transdisciplinary knowledge co-production. However, it remains a significant challenge to decide whether all three types can or should be covered in individual transdisciplinary research efforts, because it will have a decisive bearing on the strategic direction of the research in general, and the research design in particular.

Deciding what type of knowledge should be produced is informed by at least the following three factors: (a) the context and nature of the boundary problems at hand, namely what type of practical

[8] This is dealt with in more detail in the Outcomes section below.

knowledge is needed to find integrated solutions, (b) theoretical and empirical knowledge and information of similar problem situations that is already available in the literature, or should still be produced, and (c) the practical restrictions such as limited time, financial capacity and other resources that makes it more feasible to focus on one, rather than all three knowledge types in a particular individual research project. Once decided, the next important epistemological question is how to translate real-world, boundary object problems into theoretical problem statements and questions. The starting point is a shared understanding and description of boundary object problems *between* scientific experts and social actors, using non-scientific language. What is crucial is agreeing on appropriate inter-disciplinary language with which to translate the real-world problem statement *into* mutually acceptable theoretical problem statements and research questions. Guiding this process is the question whether this is aimed at producing systems, target and/or transformation knowledge, which will have a bearing on the appropriate language to be used.

The important question of whether all three knowledge types should be aimed for in an individual transdisciplinary research effort was responded to in different ways by the three researchers. There was general agreement that it would be in their best interest to focus their attention predominantly on producing systems knowledge, rather than trying to cover all three types of knowledge in equal measure. In the food security case the researcher felt that what is fundamentally needed is in-depth understanding of the different socio-cultural perceptions and agro-ecological farming practices vis-à-vis 'wild vegetables' amongst small scale farmers, before it would be possible to come up with any socially useful strategies and policies in this regard in the form of substantive target and transformation knowledge. It can be confirmed that this strategy indeed paid off as the researcher is currently furthering his ground-breaking work with both the small scale subsistence farmers and extension officers. A similar approach was taken by the researcher working on MNEs. He felt that, although much has been written in general about this topic, there was a real lack of empirical work and understanding of *what* constitutes our 'disconnect' from nature and that there was a genuine need for filling this gap. This researcher has come up with some general recommendations on personal actions and strategies that could be followed for 'reconnecting' to nature. However, substantive work in this regard was not practically possible during the three-year PhD, but is something which the researcher is currently actively pursuing with the social actors that formed part of his research effort. Of the three researchers, the student working on socio-technical innovations in the field of improving technology assessment practices was able to produce more substantive target knowledge. This was because she was working more specifically with people in the policy-making environment, both in the private and government sectors, where the need for target knowledge in the form of different scenarios for the future was explicitly stated and worked on.

Integrative transdisciplinary methodology

The notions of 'methodology' and 'methods' are quite often used interchangeably, causing unnecessary confusion at both conceptual and practical levels. The word 'methodology' is derived from three Greek words 'meta' (μετά), 'hodos' (ὁδός) and 'logos' (λόγος), literally meaning the logic, reasoning or principles (logos) guiding or underpinning (meta) decision-making when undertaking a journey (hodos). 'Transdisciplinary methodology' refers to the *integrative* reasoning, logic or principles for guiding the collaborative research process of knowledge co-production. The need for knowledge integration emanates from the need to develop *integrated* and *innovative* solutions to complex real-world problems. It is necessary to replace mutually exclusive logics and principles with

some integrative ones, capable of guiding the process of co-producing systems, target and transformation knowledge. Examples of these integrative principles in the literature on TD include: knowledge integration through recursivity, critical reflexivity, reducing complexity, contextualisation, equality (of all knowledge systems), transparency, and linking theoretical and practical knowledge (Pohl and Hadorn, 2007) (Hadorn and Pohl, 2008) (Regeer and Bunders, 2009) (Scholz, 2011) (Bergmann et al., 2013).

All three of the individual transdisciplinary researchers cited the complex nature of their boundary object issues as the core reason why a mono-disciplinary approach would not be sufficient. Rather, they should be explored via a methodology capable of integrating knowledge from across both disciplinary and non-disciplinary knowledge systems. The researchers reported positively on using the abovementioned integrative principles for guiding their research processes. Working on their guiding theoretical problem statements and research questions recursively, reflexively, transparently and equally - especially during the first year of participating in the TsamaHub summer schools and doctoral seminars - played an important role in internalising these integrative principles in an interdisciplinary context.

However, learning to use the integrative principles for guiding their research processes was not restricted to working across the different *disciplinary* boundaries. It turned into a 'double-loop' learning experience (Argyris, 1976) (Argyris, 2002) for the researchers when they started engaging with their social actors and had to explain their guiding problems statements and research questions (epistemic objects) in non-theoretical, every-day language. This required learning how to re-interpret and apply these to a real-life, developing world context with its multiple social inequalities and many different groups of people. Unlike in the developed world with its much higher levels of social and educational equality, it is critically important that transdisciplinary researchers in a developing world context learn how to navigate their way through a very different set of social conditions.

In the food security case, this meant that the researcher had to treat the tacit or experiential knowledge of rural farmers, including their deep-rooted cultural values and belief systems, as of *equal value* to his own theoretical knowledge. This had to be done in a critically reflexive manner during his entire research process, starting with the way he had to prepare for his interviews and questionnaires by finding the appropriate, context-specific and everyday language with which to re-word his theoretical problem statement and research questions. However, the researcher confirmed that working according to this critical principle, and being able to sustain this for the entire duration of his research process, was of utmost importance to him as it contributed materially to the building of trust between the farmers and himself.

In the MNEs case, the researcher had a similar experience at the start of his research journey, but, upon critical reflection, took a different direction altogether. After coming into contact with the cultural values and belief systems of the Khoi-San people it became clear to him that the problem of our 'disconnect from nature' does not exist with them, but rather with westernised people. He then decided to engage with totally different groups of people, their cultural values and belief and knowledge systems. The researcher found it necessary to explore the transdisciplinary ideas of Basarab Nicolescu (Nicolescu, 2002) and Manfred Max-Neef (Max-Neef, 2005) on different 'levels of reality' and 'levels of understanding'. Combining these ideas with those of Gregory Bateson

(Bateson, 1972) (Bateson, 2002) on different 'levels of learning', provided the researcher with new theoretical insights, making sense of moving *between* the social actors' fundamentally different ways of learning, understanding and knowing the world. This reflexive 'double-loop' learning experience – moving between theory and practice – helped the researcher to continuously re-work his guiding problem statement and research questions.

In the technology sustainability assessment case, the researcher's decision to pursue a transdisciplinary approach meant engaging with a wide range of different actors and stakeholders. These ranged from social communities, to technology developers, technology assessment practitioners, and policy-makers in various government departments. From a transdisciplinary perspective the twin challenge she faced was, on the one hand, how to make sense of the multiple perspectives, values, needs and interests of all these different actors and stakeholders, and on the other, how to integrate these multiple social viewpoints and positions into her research. Going about this recursively, reflexively, and reducing the complexity of all the stakeholder viewpoints received, whilst at the same time treating each of the viewpoints expressed as having equal value and importance, was key to the success of her research effort. Her in-depth understanding of systems dynamic modelling meant that she could facilitate each step of her research process in a thoroughly transparent manner, whilst at the same time continuously re-working her guiding problem statement and research questions.

The methodological lessons learnt from the three research cases clearly illustrate that opting for a transdisciplinary approach as an appropriate methodology for developing integrated, sustainable solutions in a developing world context comes with its own unique challenges and opportunities. These cannot necessarily be dealt with in terms of an overly methods-driven approach, which seems to be the trend of the developed North (Bergmann et al., 2013). What is common and critical in each case is the carefully constructed convergence of methodological principles and methods. By not just going about their research in a purely procedural or instrumental way, but in a critically reflexive, recursive, equal and transparent manner, the researchers were able to build individual relationships of trust and mutual interest with the various social actors and stakeholders. If TD is about doing science *with* society, and if this happens under social conditions of deep-rooted educational and other inequalities, then building epistemic relationships based on trust and shared interests are vitally important for successful transdisciplinary research in a developing world context.

Integrative methods for transdisciplinary research

The word 'methods' has its origins in the same root Greek word 'hodos' (ὁδός) as methodology, but refers specifically to the tools or instruments used with which to navigate a journey. 'Transdisciplinary methods' or rather 'methods *for* transdisciplinary research' refers to the *integrative* tools, steps and procedures used to integrate the different disciplinary and non-disciplinary knowledge systems (Scholz & Tietje, 2002) (Scholz, 2011) (Bergmann et al., 2013). The starting point in transdisciplinary research processes is always that of 'joint problem framing' and this is not something which can be achieved by merely following certain replicable steps or procedures. On the contrary, this can only be achieved if transdisciplinary processes are carefully facilitated and guided by integrative logic, reasoning and principles *in conjunction with* the appropriate integrative methods. These integrative methods can bring together different viewpoints of a particular problem situation, and synthesise these not only into a joint framing of the problem,

but also into a set of joint research questions, which in turn need to be jointly researched, again using integrative methods.

Transdisciplinary research processes are always embedded in a particular set of historical and social conditions. This reaffirms that context matters in transdisciplinary research, especially when considering which methods may, or may not, be appropriate integrative tools. The decision-making process over methods needs to be guided by integrative logic, reasoning, and principles. For example, when looking at the specificity of the complex problem situation at hand and the social conditions under which it emerged, the following questions should be asked: (i) who are the scientific and social actors involved in the research process; (ii) what are the relationships or connections between these actors; (iii) have they ever worked together before; (iv) what is their current knowledge of the problem situation, and what type of knowledge should be co-produced? It is important that answering these questions is done in a critically reflexive, recursive, and transparent manner, which gives equal value to the different viewpoints.

All three of the researchers were faced with the question of which integrative methods to use. It was not just a once-off decision at the start of their research processes, but rather a continual decision as their research efforts unfolded. Most importantly, their understanding of their social actors' interests, expectations and educational competencies increased. The three researchers ended up using a wide range of quantitative, qualitative and transformative methods. The researcher on food security used a combination of: ethno-botanical surveys and structured questionnaires to collect quantitative data on soil management, including the farmer perceptions and attitudes to indigenous vegetables, and the diversity of the vegetables; purposive sampling to select the study area, fields from which soil and plant samples were taken; and standard blocking techniques, such as randomised complete block design (RCBD), to conduct plant and soil studies. The researcher working on improving sustainability technology assessment interventions used a combination of: a case study of biodiesel production development in the Eastern Cape Province of South Africa; simulation, with specific use of system dynamics modeling; surveys, interviews and focus group discussions for the validation, verification and usefulness analysis of the system dynamics model and literature for developing a conceptual framework. The researcher working on MNEs used a combination of the following qualitative and transformative methods: on-line surveys or questionnaires; in-depth interviews; focus group discussions; participative observation; analysis of interviews with Atlas.ti qualitative analysis software; and participatory action research, including group dialoguing during purposely arranged wilderness trails for this purpose.

As can be seen, the researchers adopted a mixed methods approach (Bergman, 2008) as a means of achieving the overall integrative function required from integrative methods in transdisciplinary research. However, on critical reflection, and in the words of the researcher working on MNEs, it was not so much the methods *per se*, but the philosophy and guiding principles underpinning the transdisciplinary approach, which were most useful in navigating their individual research processes. This is an important point that will be further discussed in the Outcomes section below.

Transdisciplinary outcomes: Practically useful and theoretically new knowledge

As already alluded to in the Introduction, the twin goal of collaborative transdisciplinary research processes is to co-produce outcomes that could be *both* socially useful and scientifically innovative (Jahn, 2008) (Scholz, 2011) (Jahn et al., 2012) (Lang et al., 2012) (Bergmann et al., 2013). Socially

useful outcomes include, inter alia: new policies, strategies, interventions, institutional arrangements, action plans, and critically important transformation knowledge which may help in transitioning to a more just and sustainable society (Swilling and Annecke, 2012). Scientifically innovative knowledge includes, inter alia: new theories about a particular societal problem, formulating new integrative methodological principles for guiding the transdisciplinary research process, and designing new integrative methods for doing transdisciplinary research, and so forth.

Producing knowledge that is only socially useful will turn TD merely into a practical problem-solving tool with little or no incentive for scientists to stay involved. Similarly, producing theoretical knowledge that only provides new ways of explaining and understanding the societal problems we are facing today *without* contributing to their transformation will turn transdisciplinarity into something producing abstract or de-contextualised knowledge only, with little or no incentive for social actors to stay engaged. Therefore, the goal of co-producing knowledge that is both socially and theoretically useful and innovative, results in a creative tension that needs to be skilfully facilitated during the entire collaborative process.

The emerging outcomes of the three researchers are providing some important insights into what can be achieved when undertaking individual transdisciplinary research. In terms of new theoretical outcomes, innovation did not so much occur at the methodical level of having designed and used new integrative methods, but from the way they went about conducting their research projects at the epistemological and methodological levels. All three researchers followed very different research strategies of working with and building informal individual epistemic relationships with the social actors immediately available to them. These epistemic relationships in turn created the much needed time and space for the researchers to work reflexively and recursively.

However, these more informal individual epistemic relationships were unintentionally transformed into socio-epistemic relationships as they were not only focussed on the epistemic objects of the researchers, but equally so on the real-world issues of the social actors involved. This in turn meant that these socio-epistemic relationships took on a 'social existence' *beyond* the individual research projects; something that all three of the researchers have returned to and are still working on *after* their individual research projects. The unintended consequences produced by these socio-epistemic relationships, and the way the researchers are responding to them, opens up exciting new possibilities of co-producing systems, target and transformation knowledge in individual transdisciplinary research projects and processes; thereby coming closer to achieving the twin goal of producing practically useful and theoretically innovative knowledge.

The interpretation of the careful construction of these epistemic relationships and their transformation *into* socio-epistemic relationships may very well lay the foundation for 'transdisciplinary epistemic communities'. According to our knowledge, this is a new construct that has not been theorised to date in the literature on TD. It therefore opens up possibilities of systematically inquiring and conceptualising something which, in future, may be more explicitly and intentionally included in the research design and strategies of undertaking individual transdisciplinary research. This is particularly useful for circumstances where it is not possible to participate in already-existing multi-stakeholder research processes, or make these very time- and resource-intensive processes part of the research design of individual research projects.

The notion of 'epistemic communities' has of course been widely published in a range of social science literature, including the literature on inter- and transdisciplinarity. However, the researchers' experience was something qualitatively different. In the literature on inter- and transdisciplinarity, an 'epistemic community' is something which has origins, existence and functioning in the academic environment, essentially *across* and *between* the social sciences and humanities (Klein, 2008). Meanwhile, in the literature on cities in a developing world context, for example, 'epistemic communities' have been thought of as having their genealogy, existence and functioning in civil society, essentially in the social spaces existing *between* the state and the private sector (Pieterse, 2006).

What is fundamentally missing from these perspectives is the joint presence of science and society in their formation and functioning. In the case of interdisciplinary 'epistemic communities', society is simply absent from how they are being constructed and what they produce; similarly, academia or science does not feature in the way civil society's 'epistemic communities' are understood. This is very different from the observations of the researchers' work. Even in its current rudimentary form, their research is pointing to a much more 'hybrid' phenomenon in which 'transdisciplinary epistemic communities' can be constructed *from* individual transdisciplinary processes; the starting point of which is the careful building and developing of informal socio-epistemic relationships between science and social actors.

Conclusion

Our research has shown that if the 'idiographic' dimension (Krohn, 2010) of individual transdisciplinary research is taken seriously, much can be learnt from what can be achieved at the more local or micro level of inquiry. At the ontological level, it is possible for individual transdisciplinary researchers to immerse themselves in their individual research efforts, to explore different facets of the complex problems at hand at 'deeper' levels than what may normally be possible when conducting more formally structured transdisciplinary case studies. At the epistemological level, the relational challenges of transdisciplinary knowledge co-production is something that can certainly be taken on by pursuing a different research strategy of working with and building informal, individual social actor relationships, thereby creating the necessary opportunities for working with guiding problem statements and research questions. Participation in bigger transdisciplinary efforts is not a pre-condition in this regard. At the methodological level, continuously guiding the individual transdisciplinary research process in a reflexive, recursive, transparent and equal manner is absolutely critical, because transdisciplinary research processes cannot be done successfully if dominated by overly methods-driven approaches. At the methodical or methods level, there are indeed numerous quantitative, qualitative and transformative methods which the individual transdisciplinary researcher can use as appropriate integrative methods. These depend on how the process of individual epistemic relationship building is unfolding and the different contexts within which the individual researcher is working.

As far as the outcomes of individual transdisciplinary research work are concerned, taking the developing of individual epistemic relationships to the next level of working towards and building what we called 'transdisciplinary epistemic communities' is a significantly new proposition for inclusion as an intentional aspect of transdisciplinary research design, as well as tracking and studying the social and theoretical outcomes that may emerge. However, we acknowledge that this

notion of 'transdisciplinary epistemic communities' is still a concept in its infancy and needs a lot more work before it may be theoretically and practically useful. From our initial observations and reflections, we would like to propose the following pointers for taking this work forward:

- The issues that 'spark' transdisciplinary epistemic communities into existence (Marres, 2007) are typically socio-ecological boundary problem situations, situated at the interface of science and society, warranting transdisciplinary responses from social and science actors to work across disciplinary and non-disciplinary boundaries in search of integrated, sustainable solutions.

- In a developing world context, boundary problem situations would normally centre on issues such as food security, poverty, waste, for example. However, they need not be restricted to 'hard', material issues but could include 'non-material' issues, situated in our subjective experiences of nature, and warranting a radically different response or reorientation of our relationship to nature.

- Transdisciplinary epistemic communities are fundamentally network-like structures, of which the most basic elements would be informal 'dyadic' relationships and nodes (Johnson 2009) between individual science and social actors, who mobilise themselves around finding integrated, sustainable solutions to context-specific boundary problem situations.

- Building transdisciplinary epistemic communities is not dependent on the existence of the same set of egalitarian socio-political conditions as presumed by the ideal-typical Habermasian model for doing transdisciplinary case study research (Scholz, 2011). On the contrary, by focussing on building informal network-like relationships, transdisciplinary epistemic communities can be assembled under very different social conditions of unequal knowledge and power relations.

- Individual transdisciplinary research projects may be the starting point of developing necessary informal, individual socio-epistemic relationships for the formation and functioning of transdisciplinary epistemic communities.

- Working according to integrative principles and methods of transdisciplinary knowledge co-production processes, while also designing and bringing new ones into the process, are key to developing durable socio-epistemic relationships.

- The different roles of reflexive scientist, facilitator and intermediary (Pohl et al. 2010) as well as competencies and capabilities of relational, anticipatory, normative and strategic thinking (Wiek et al., 2011) will also be critical to how the individual transdisciplinary researcher interprets and carries out the developing of these informal socio-epistemic relationships.

- The initially informal, individual relationships may very well over time be further developed and transformed into more institutionalised relationships, becoming more formal and structured multi-stakeholder forums, depending on societal interests and resources.

This is by no means an exhaustive list, but rather a guide for more systematic inquiries and reflections into the formation, functioning and effects of transdisciplinary epistemic communities.

There could indeed be many more issues that will emerge during the course of such investigations, which we hope may result from this paper.

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