

Accepted Manuscript

Title: Beginning at the End: The outcome spaces framework to guide purposive transdisciplinary research

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PII: S0016-3287(14)00168-2

DOI: <http://dx.doi.org/doi:10.1016/j.futures.2014.10.007>

Reference: JFTR 1967



To appear in:

Received date: 1-4-2014

Revised date: 8-10-2014

Accepted date: 16-10-2014

Please cite this article as: C. Mitchell, D. Cordell, D. Fam, Beginning at the End: the outcome spaces framework to guide purposive transdisciplinary research, *Futures* (2014), <http://dx.doi.org/10.1016/j.futures.2014.10.007>

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Beginning at the End: the outcome spaces framework to guide purposive transdisciplinary research

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Abstract (200 words)

The framework presented in this paper offers an alternative starting point for transdisciplinary research projects seeking to create change. The framework begins at the end: it distinguishes three distinct

'transdisciplinary outcome spaces' and proposes articulating their content for purposive transdisciplinary research projects. Defining upfront the desired improvements has profound implications for how transdisciplinary research is conceived, designed, implemented and evaluated.

Three key realms of transdisciplinary outcome spaces are distinguished – situation, knowledge, and learning – and elaborated: (1) an improvement within the 'situation' or field of inquiry; (2) the generation of relevant stocks and flows of knowledge, including scholarly knowledge and other societal knowledge forms, and making those insights accessible and meaningful to researchers, participants and beneficiaries; and (3) mutual and transformational learning by researchers and research participants to increase the likelihood of persistent change.

Positioning the framework in the field of transdisciplinary literature reveals that much of the contestation concerning transdisciplinary research and practice may be attributable to the diverse but implicit ontological and epistemological perspectives inhabited by transdisciplinary researchers, leading to a call for more reflexive and explicit attention to these and other formative influences (i.e. sources of funding, project motivation, or locus of power).

HIGHLIGHTS

- Purposive transdisciplinary research projects seek to create change
- Articulating desired changes upfront affects design, implementation, evaluation
- A framework to distinguish between outcome spaces can clarify desired changes
- Outcome spaces are distinguished as the situation, knowledge, and learning
- Making worldviews and other formative influences explicit is good practice

5 *Keywords:* transdisciplinarity, outcome spaces, sustainability, research design, purposive research

1 Introduction

Over the last four decades there has been increasing interest in transdisciplinary research. The complex, messy nature of sustainability problems which cannot easily be tackled from a single disciplinary perspective makes a transdisciplinary approach valuable (Lawrence, 2010, Hirsch-Hadorn et al., 2006). With increasing literature on transdisciplinarity emerging in the field of sustainability science comes a

diverse range of perspectives. In part this diversity reflects the disciplinary characteristics of the researcher, how transdisciplinary research is perceived, practiced and theorised and the potential influence of funding models as well as disciplinary perspectives and history of the researchers involved. The majority of literature on transdisciplinary research tends to focus on the input and/or process of research rather than explicitly acknowledging the outputs or outcomes of the approach. The conceptual model of transdisciplinary research presented in this paper offers a complementary starting point by first acknowledging the normative intent of deliberately creating change toward sustainability and then articulating the desired outcomes through the concept of 'outcome spaces'.

This paper proposes a new framework – *transdisciplinary outcome spaces* – to guide purposive (after Jantsch, 1972) transdisciplinary research (i.e. research that seeks to create change). The three outcome spaces are defined as (1) an improvement in the situation or field of inquiry, (2) the generation of relevant stocks and flows of knowledge, and (3) mutual and transformational learning by the researcher/s and involved participants. This new framework is a distinct contribution that complements and extends both Jantsch's (1972) original model (see figure 1) and Holm et al.'s (2013) radical inter- and transdisciplinary environment (RITE) framework. It also can be seen as a response to Klein's (2013) call for transdisciplinary researchers to communicate 'about how to strengthen both their local projects and their common goals', and to Lawrence's (2010) 'applicability gap'. To achieve the outcomes articulated in the framework, we propose a systemic approach to transdisciplinarity, which brings into focus the relationships between the entities and components in transdisciplinary research – the outcome spaces (i.e. Situation, Knowledge, Learning) and the causal links and interplays between them. In this way the framework is concerned with the interface between research and practice.

This paper explores the premise that explicit and upfront structuring of the outcomes of purposive transdisciplinary research in particular ways has profound implications for the conception, design, implementation and evaluation of individual research projects. In this paper, we position the proposed framework within the field, firstly by arguing for a richer kind of reflexivity in practice from transdisciplinary researchers, and secondly by examining the attributes of transdisciplinary research and their significance for research design and practice. We then identify and detail three essential and distinct outcome spaces for purposive transdisciplinary research, describing their attributes and significance and how they contribute to change. The overlaps, tensions and mutually reinforcing potential between the outcome spaces are explored. Finally, we draw implications and conclusions for the field of transdisciplinary research and practice.

2 Positioning the 'Outcome Spaces Framework'

2.1 A reflexive approach to positioning transdisciplinary intents

While there is broad agreement that transdisciplinary research is needed to deal with complex societal challenges (e.g. eradicating poverty, responding to climate change) that cross boundaries and disciplinary knowledges (Horlick-Jones and Sime, 2004, Wickson et al., 2006, RESCUE (nd), Holm et al., 2013), transdisciplinary research remains a contested concept (Pohl, 2011, Lawrence, 2010, Miller et al., 2008). The intents of transdisciplinary research vary widely (e.g., normative, descriptive, transformational) with a range of approaches and models used by transdisciplinary scholars and practitioners and others in related fields (e.g. Bammer, 2013). Ison (2008) notes that the existence of this variance brings with it a special responsibility: as authors and practitioners contributing to the development of transdisciplinary research processes, there is an obligation beyond positioning our work in the field of possibilities to be explicit about revealing conceptual, ontological, and epistemological positions. This section seeks to do both.

One means of responding to the diversity in the field is to categorise, typologise, and structure transdisciplinary approaches. Recent leading efforts include Pohl's (2011) distinction based on 'purpose', Jahn et al.'s (2012) overarching model for the practice of transdisciplinary research, and Klein's (2013) keyword spectrum analysis. In what follows, we position this paper within these realms.

Pohl (2011), building on Carew and Wickson (2010), proposed four distinct purposes as being sufficient to describe the spectrum of notions of transdisciplinary research. He proposed three distinct groupings of these purposes as a structure for understanding the conceptual diversity of transdisciplinary approaches. Whilst Pohl (2011) uses the term 'purpose', we suggest the focus of his characterisation is more 'what' and 'how' than 'why' i.e., focused more on descriptions and means than outcomes and ends. This

distinction is significant here because this paper is focused on the outcomes of transdisciplinary research.

All three of Pohl's groupings share the fundamental descriptions of 'relating to socially relevant issues' and 'transcending and integrating disciplinary paradigms'. The characterisation of his first grouping stops here. The second grouping has an additional commitment to 'participatory research', whereas the third grouping is characterised as 'searching for a unity of knowledge'. The approach to transdisciplinary work that underlies this paper is situated within this grouping, wherein the initial commitment is to the re-purposing of disciplinary knowledge to gain traction on complex societal issues, whilst preferencing not just participation in the form of consultation, but rather strong engagement with professional and lay knowledges, beginning with the articulation of the societal issue to be addressed (Mobjörk, 2010). This commitment has significant consequences for the framework explored in this paper.

In taking this stance, we align ourselves, like Holm et al. (2013), with Jantsch's (1972) view of transdisciplinarity, elaborated in his contribution to the earliest enunciations of the term at an international seminar on interdisciplinary teaching and research for OECD member countries, held in France in 1970. Jantsch (1972) described his elaboration of inter- and transdisciplinarity as complementing whilst 'venturing out farther' than Piaget's (1972) epistemology of interdisciplinary relationships which focused on structures, causal linkages and co-operation between disciplines at the same hierarchical level. From Jantsch's perspective as a systems and futures scholar, purpose and meaning are central: inter- and transdisciplinarity are the result of 'purpose-oriented co-ordination from a higher level' in order to 'deal(ing) effectively with systems in an integrative way (Jantsch 1972, p101)'.

Jantsch was seeking less to define transdisciplinarity *per se*, and more to respond to the 'current situation of mankind [sic]'. He saw transdisciplinarity as an inductive principle for expressing human systems creation. Figure 1 is an adaptation of Jantsch's (1972) education/innovation system, comprising four hierarchical levels: empirical, pragmatic, normative, and purposive, each with its own organising language (e.g. logic for the empirical level), and linked by the overarching languages of systems and organisational theory. Jantsch's model shows how what constitutes the nature of a transdisciplinary effort is determined by the function of the 'meaning' level, where he exhorts us to 'search for and bring into play' values and norms. It is precisely those values at the purposive level that determine the principles, structure and function of the transdisciplinary 'education/innovation system' at work: the direction will be different if they are Christian progress or ecological balance or cyclical development from a Buddhist perspective (Jantsch 1972). Positioning the approach to transdisciplinarity that underpins this paper therefore requires an introduction to the practice from which it arose.

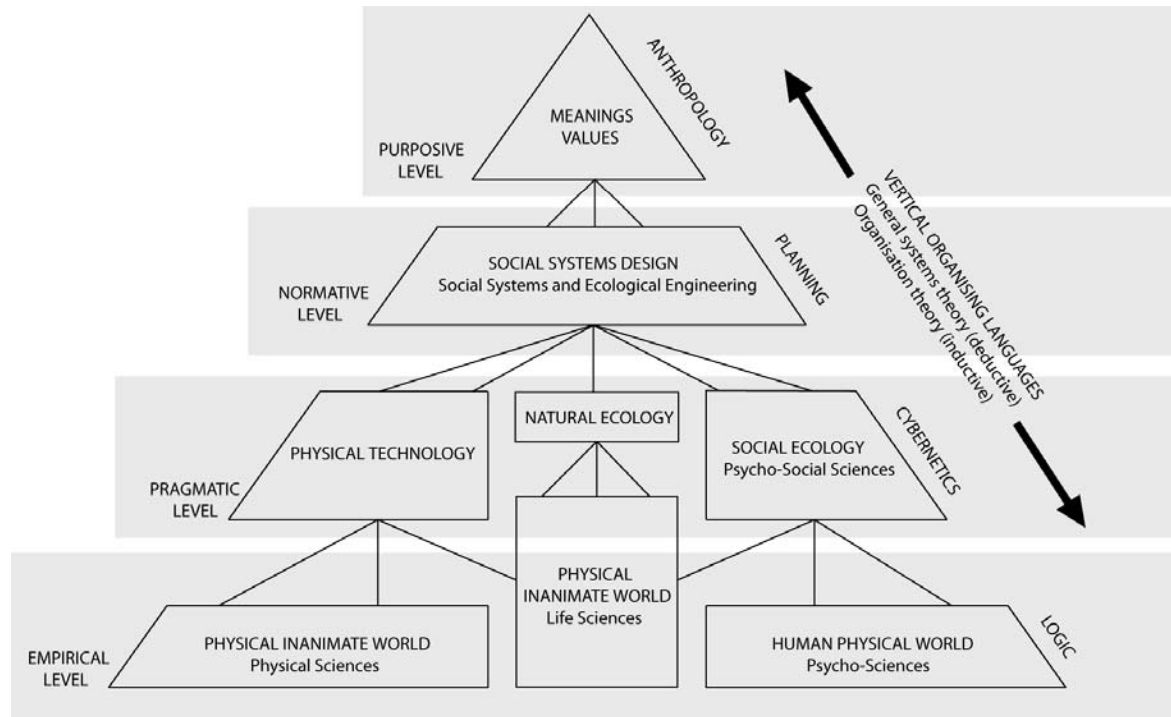


Figure 1: The Education/Innovation system, viewed as a multi-level, multi-goal hierarchical system (Adapted from Jantsch, 1972).

The Institute for Sustainable Futures at the University of Technology Sydney conducts project-based research funded by fee-for-service or grants (see www.isf.uts.edu.au). The mission of the Institute for Sustainable Futures is *to create change towards sustainable futures* therefore its transdisciplinary research is often undertaken within an explicitly normative, change-creation paradigm and seeks to engage government, industry, community and other research stakeholders in the inquiry, change creation and knowledge production process. This process recognizes that research, mutual learning and co-generation of knowledge by researchers and stakeholders can be powerful tools for creating change and improving the social robustness of academic research. ISF's 50 research staff and 25 research students are interested in how change occurs and their role in facilitating change. ISF often has a deliberate and ongoing involvement in the situation beyond the life of the project. Like Jantsch (1972), ISF's research is informed by insights from systems thinking and futures. Thus this type of research sits squarely within Jantsch's purposive intent of taking on 'the challenge of restructuring the joint systems of society and technology (p101)'.

The position we take is that transdisciplinary praxis is neither objective nor value-free. Whilst this position shares Jahn et al.'s (2012) need for a reflexive process, it stands somewhat in opposition to their model for transdisciplinary research which has as its first step 'problem transformation', wherein a societal problem is mapped onto a scientific problem – a 'problem [is] displaced from the world of needs, interests, and values into the realm of scientific rigor [sic] and objectiveness (Jahn, 2012, p.5)'.

Our starting point in this paper is to acknowledge that each of us has epistemological and ontological preferences as a transdisciplinary researcher and values as a person in society, and that these preferences and values provide the lenses through which we interact with the world. Those lenses determine for example, what we as researchers notice, what is hidden, what is chosen for inclusion within the boundaries of analysis, and how we as researchers respond to what we experience. This ontological position may account for the difference between the approach to transdisciplinary research described in this paper and Jahn et al.'s (2012) model. Jahn et al. appear to conceive of a 'problem' as an ontological entity – in Checkland's (2000) terms, something that exists in the real world, which can therefore be transformed into an object for rigorous and objective scientific investigation.

In contrast, the epistemologically pluralist praxis (Miller et al., 2008) that underpins this paper follows Schon's (1987) reflective practice in the 'messy swamp' and Checkland's (2000) Soft Systems Methodology, and treats situations as epistemological entities, imbued with the qualities of the multiple perspectives engaged in the process of improvement. There is no value judgement in this distinction – only the observation of the impact of ontological and epistemological preferences on what constitutes transdisciplinary research. Therefore, the best we can do as transdisciplinary researchers is to continue to improve our individual and collective capacity to practise reflexively, one part of which means to make explicit these preferences and values, and to notice the impact they have on our research praxis (see also Ison 2008).

The purposive approach to transdisciplinary research that underpins this paper maps reasonably well onto the 'spectrum of keyword sets' eloquently articulated by Klein (2013): interdisciplinarity, unity/complexity, participation/collaboration, knowledge and transgression. The purposive intent brings with it a focus on holistic thinking that generates new degrees of blurring of and synthesis across boundaries. It cultivates heterogeneity, supports the emergence of new ways of operating, and is interested in improving the coherence between espoused goals and day-to-day actions, all of which sits more or less comfortably with the notions of epistemological plurality (see also Miller et al., 2008) and a 'moral project'. Participation is central to this approach since the goal is to create change, which occurs principally through the decisions and actions of research collaborators and requires a commitment to deep collaboration, networking, and mutual learning. Both stocks and flows of knowledge are central to the framework proposed in this paper, with a focus on knowledge for its use in action, which aligns with Klein's (2013) concepts of socially robust, contextual, and co-produced knowledge alongside new knowledge distribution mechanisms.

2.2 Core Attributes of Transdisciplinary Research and Researchers

There are many ways to do transdisciplinary research and this, in part, depends on the intention of the research (e.g. descriptive or normative), the starting point, funding source (e.g. client or research grant), level of engagement with theory (including crossing disciplines from physical to social sciences), level of engagement with practice (including government, industry, the community). While there is no right or wrong, it is important to consider these aspects explicitly and make them transparent to both the project team and primary audiences. In table 1 we outline key attributes of a transdisciplinary researcher and how these components characterise the nature of the transdisciplinary project.

Table 1: Core attributes of transdisciplinary researchers

Aspect	Significance
<i>Intention</i>	What is the intent of the research project? (i.e. purposive, normative, descriptive?). e.g. the research might be outcomes-focused with a (moral) commitment to improving the situation, or the intention may be to better understand the situation.
<i>Worldview</i>	What is the worldview or orientation of the research team? This can influence the theoretical lens, in addition to where boundaries are drawn around the project and the problem situation, and, which stakeholders participate and who are excluded.
<i>Experience and qualifications</i>	What are the existing qualifications, formal training, skills? Life experiences? Sense of role and responsibility in the project? This will also likely influence the theoretical framework and methods selected by the team, in addition to the quality of

research.

<i>Past engagement with the situation</i>	What past experience, engagement or relationships in the situation under investigation does the research team have? This could positively or negatively influence trust in the researchers by other stakeholders, such as perceived reputation (e.g. 'street cred' or perceived as 'invested' in a particular situation as changing or staying status-quo).
<i>Funding arrangements</i>	Who is funding the research? This has implications both in terms of the outcomes of the research (e.g. whether it is likely to be implemented by the funding body – e.g. a government department or water utility); and, in terms of trust (e.g. if funded by a particular industry/governmental group the research may be perceived by others as biased if care is not taken to ensure independence)
<i>Degree of engagement across disciplines</i>	What is the degree of engagement across theoretical and epistemological perspectives? E.g. across social sciences, engineering, political economics, ecology, systems thinking? Or within the same theoretical/epistemological framework? (e.g. biology, geology, engineering etc). This has implications in terms of the degree of transdisciplinarity, and hence opportunities for emergence and insight through engagement across disparate philosophical perspectives.
<i>Degree of engagement with the situation</i>	What is the degree of engagement across sectors and stakeholder groups? E.g. across governmental, industry, NGO, community and other organisations? Or is it limited to one stakeholder group (such as industry)? This has implications in terms of breadth of perspectives included in the analysis, and hence the outcomes. It may also influence the saliency, credibility and legitimacy of the research if it has engaged widely among stakeholders.

In this way, the attributes of a transdisciplinary researcher (as elaborated in Table 1) can profoundly influence the nature of a transdisciplinary project. For transdisciplinary research whose 'top coordinating function', in Jantsch's (1972) terms, is sustainable development, outcomes matter. However, the focus in the literature on the process of transdisciplinary research seems to have combined with the epistemological and ontological variety in transdisciplinary research to produce a gap in which outcomes are taken as read (i.e., the common good (e.g. Pohl and Hirsch-Hadorn, 2008)), focused on scientific elaboration and publications (Scholz et al., 2006), or thought of as part of the process e.g. mutual learning (Jahn et al 2012). What follows is a detailed explication of a new framework that seeks to reflexively address this gap.

3 Outcome Spaces

3.1 Transdisciplinary outcome spaces – introducing a conceptual framework

The transdisciplinary outcome spaces framework introduced in this paper provides a conceptual framework to guide the conception, design, conduct, and evaluation of purposive transdisciplinary research projects. Here we define 'framework' (after Ostrom, 2005) as a set of organising principles that helps identify the elements in a system under study and the relations between the elements, helps guide the inquiry, and helps analysts generate questions. Like others, we view transdisciplinarity as a practice, rather than an institution (Russell et al., 2008) or a theory (Jahn et al., 2012).

The transdisciplinary outcome spaces framework takes a backcasting approach (Robinson, 1982, Dreborg 1996) in that it begins at the end. It extends Scholz et al.'s (2006) 'backward planning' approach in two significant dimensions. Firstly, it provides a framework for what to consider in their initial step of 'goal formation and case faceting' and in so doing, it qualitatively extends the types of outputs considered in their 'elaboration and documentation' phase. Secondly, this framework takes an explicitly epistemologically pluralist stance to knowledge and knowledge production, encompassing all three of Miller et al.'s (2008) domains: 'mechanistic', 'contingent' and 'critical'. In contrast, Scholz et al.'s (2006) 'TCS [transdisciplinary case study] methodology ... is designed along the principles of the Probabilistic Functionalism' (p232), which would seem to place their epistemology of knowledge principally in the 'mechanistic' domain with extensions into the 'contingent' domain. The framework also helps to disentangle qualitatively different outcomes, allowing researchers and participants alike to tease apart more (changes in the situation) and less (learning) instrumental research outcomes, supporting the kind of richer conversations that are necessary in radical inter- and transdisciplinary research (Holm et al., 2013).

The framework articulated here has emerged from 17 years of transdisciplinary praxis at ISF. Research staff and students at ISF have been working with this conceptual framework of three distinct but overlapping and interlinked transdisciplinary outcome spaces in project research (Mitchell, 2009, Mitchell and Willetts, 2009) where, as Checkland (2000) notes, theory informs practice which informs theory. Whilst the detail of the framework has evolved, the fundamental distinctions of knowledge, situation and learning have stood the test of time (figure 2).

The first outcome space is improvement within the 'situation' or field of inquiry, that is, the everyday world of our research collaborators and clients. Changes in the situation may be institutional (e.g. a shift in a policy), or biophysical (e.g. more efficient water use). Secondly, the generation of relevant stocks and flows of knowledge, including rigorous scholarly knowledge and other forms of knowledge (e.g. decision-making tools, industry reports, interactive websites, apps) in order to make insights accessible and meaningful to both research participants i.e. clients and collaborators, as well as broader beneficiaries i.e. industry sectors and/or citizens. Finally, outcomes of mutual and transformational learning by both researchers and research participants increase the likelihood of persistent change.

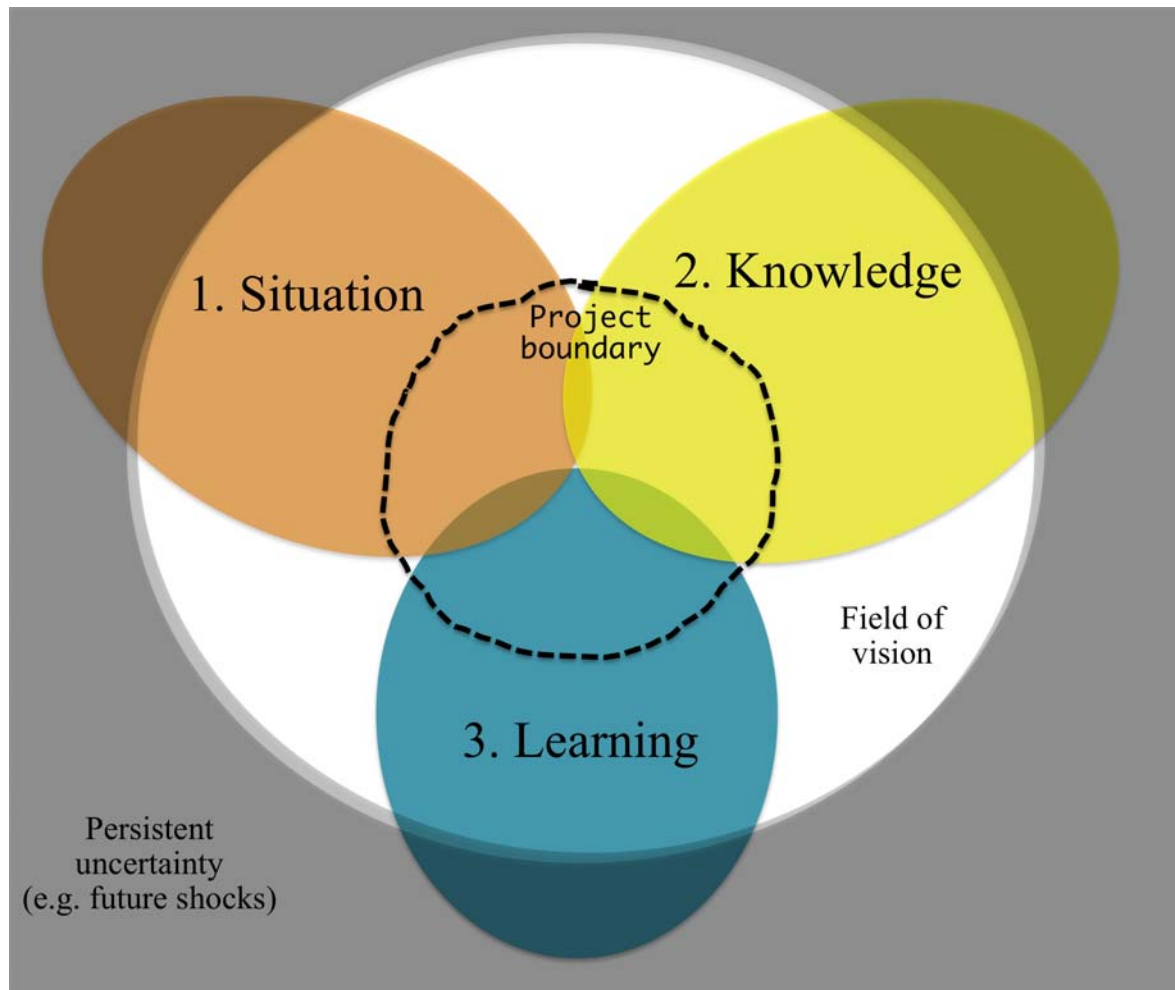


Figure 2: Conceptual map of the three outcome spaces (1. Situation, 2. Knowledge, 3. Learning) indicating a transdisciplinary project embedded in the broader landscape.

The conceptual map of outcome spaces in figure 2 indicates the transdisciplinary project embedded in a broader context of the situation, knowledge and learning spheres within a field of vision. The field of vision is limited to the experiences, knowledge and worldviews of the research team. It represents the 'messy situation' (Checkland, 2000) as seen by researchers and participants. Beyond this field of vision is the unknown, including future persistent uncertainty (Kinzig et al., 2003) that is, what we don't know we don't know, such as future shocks. The project boundary acknowledges that project resources also bound research in time and space, requiring strategic thinking about realistic spheres of influence, and how contained research projects can leave a wider positive legacy.

Positioning the framework in relation to transdisciplinary research projects in particular, rather than transdisciplinary research in general, is deliberate and significant. That is, in the case of ISF, the framework has emerged from project-oriented praxis as a self-funding research institute conducting either research staff projects in which the scale is determined by the size, duration, and source of funds, or graduate student projects in which the scale is determined by the nature of their research degree (PhD or Master's). In either case, the project is a clearly bounded area of activity.

In the subsequent sub-sections, we expand each outcome space in relation to what it is, why it is important, what its attributes are and how it contributes to a purposive intent to create change.

3.2 Improving the Situation

The term 'situation' describes the area of our inquiry – the everyday world of our collaborators and clients – and deliberately avoids the pitfalls of a commitment to the 'problem metaphor' (Ison, 2008). It recognises the inadequacy of the idea of 'solving a problem'. Early articulations of the outcome spaces framework instead proposed 'problem re-solution', a deliberate wordplay intended to acknowledge that the messy or wicked problems are rarely 'solved' once only, and that as research proceeds, clarity improves. The term 'situation' is better still since it avoids the closing-down, negative effect of the 'problem' frame altogether (Cooperrider et al., 2003). It echoes Checkland's (2000) soft systems methodology, and its intent to foster 'accommodations' that facilitate action to improve a 'perceived real-world problem situation' and Critical Systems Thinking's (Midgely, 2003) explicit commitment to 'improving the situation'.

The outcome for the situation space is that as a result of purposive transdisciplinary research, there should be some discernable difference – a tangible and articulable improvement in the situation. These improvements can occur at different levels – a change in strategy (e.g., an organisation revising its objectives, replacing an intention to minimise harm with a restorative intent), a shift in a policy (e.g., to support investment in decentralised infrastructure), or the uptake of a new tool (e.g. a model that treats water or energy or transport demand and supply options equally, so that investing in reducing demand becomes a real option for consideration). The situation includes social and physical components of both the content and process of the project. That is, human aspects such as norms, values, and institutions in their broadest sense (Ostrom 2005), and material aspects such as infrastructure and natural systems.

Defining the situation with respect to the research project is essential for those projects that seek to create change in the situation at large. Seeking to improve the situation requires patience as well as a deep and reflexive appreciation of how change happens and the roles of researchers and participants. Sometimes, small changes, step by step, project by project, eventually lead to revolutionary changes. Thus, the influence of a project may occur after the lifetime of the project. Factors external to a particular project, such as change in government, can also provide windows of opportunity for significant change or for qualitatively different types of change.

Explicitly articulating the project boundary (in space and time) within the larger situation context is necessary. What is included and excluded will be subjective (Midgely, 2003), and motivations for the project impact on how the situation is perceived. The location of the original initiative is material, both in terms of the type of organisation (such as an industry association, a government utility, a commercial development company, a transdisciplinary research institute, etc.) and the positional power of the instigator/s within their organisation.

The situation may be dynamic and change over the course of the project. Therefore the situation includes current influential triggers, drivers, players, and trends, as well as project participants and changes in their perceived area of control and influence. In defining a transdisciplinary project, participating stakeholders should ideally be involved in jointly defining the project boundaries (Spandenberg, 2011). The worldview, intention, expertise and agenda of participants will influence what is chosen for inclusion within the boundaries of analysis. Core attributes of transdisciplinary researchers (see Table 1) therefore have the potential to influence where boundaries are drawn around the project and the situation, and which stakeholders either participate in the project or are excluded.

For purposive transdisciplinary research, improving the situation is a fundamental goal, therefore changes in the situation need to be monitored and evaluated, both in terms of how the project has and might influence the broader situation towards a more sustainable trajectory, and to better assess (e.g. the efficiency, efficacy, and effectiveness, and perhaps even ethics and elegance (see Checkland 2000)) of these types of interventions, so that they may be repeated, refined and improved. In the same way that contributing and engaging in academic knowledge production involves a *peer-review* process to critique and ground-truth the researchers' work, engaging in the societal context can facilitate a form of *stakeholder-review* process that reality-checks and critiques the arguments, assumptions and language of the research (Cordell, 2010).

3.3 Contributing to Knowledge Stocks and Flows

For purposive transdisciplinary research, the flows of knowledge are as important as the stocks. In system dynamic terms, stocks are linked by feedback loop flows, and ‘without timely feedback, there can be no timely response’ (AtKisson, 1999, p.77). Where the goal is, for example, to create change towards sustainable futures whilst dealing with messy systems, opening new feedback channels and speeding up the flow of feedback is essential. In addition to transparency and rigour, such that the quality of the work is independently assessable, that requires accessibility (e.g., a wide range of delivery and dissemination strategies in order to make contributions available to wide-ranging groups) and inclusiveness (i.e. the artefacts are designed to be interpreted by wide-ranging audiences).

In this framework, ‘flow’ relates to how knowledge moves: between disciplines; between theory and practice; between academic and professional practice; from within to outside the project; up and down Jantsch’s (1972) empirical, pragmatic, normative and purposive strata, etc. That is, the mechanisms by which memes of transdisciplinary research insights are transported and transferred between people of shared and different ontologies, epistemologies, worldviews, or ‘thought-styles’ (Fleck, 1986). Thus, contributions to knowledge stocks and flows occur via things that others can find, engage with, apply and/or adapt, and include tangible and accessible knowledge artefacts such as peer-reviewed publications and reports as well as blogs, websites, resources, policies, guidance materials, presentations, apps, social and conventional media, etc encompassing both the content and process of transdisciplinary research.

The form of each knowledge artefact should be purposively constructed and located to reflect the desired change. For example, a detailed peer-reviewed journal article targeting scientists, a brief to-the-point summary for engaging policy-makers, or a media release and public website using popular science or layman’s terms for reaching the general community. Similarly, purposeful placement or ‘housing’ of the knowledge artefacts enables change creation. Targeting the right suite of artefacts to the right suite of audiences in the right ways at the right time means proactive and strategic ‘product’ placement to influence and enhance the diffusion (flow) of the knowledge contributions. The production, sharing, making public, and exchange of tangible knowledge artefacts is a significant means of extending a project’s influence beyond its boundaries.

Transdisciplinary research aimed at creating change requires recognition of personal, professional and academic knowledge (Klein 2013), and the diversity within each of these. Ranging across academic knowledges and epistemological divides raises significant questions and discomfort (Holm et al., 2013) about what and whose knowledges are valid, since validity is largely epistemologically determined (Miller et al., 2008). Incorporating once-excluded forms of knowledge, such as lay understandings (now acknowledged as ‘citizen science’ (<http://www.nature.com/news/2010/100804/full/466685a.html>)), is necessary, and challenging in practice (Klein 2013). Expert professional and academic knowledge is different from lay knowledge, so whilst they are not substitutable, they both may be valuable in making sense of a particular context, and therefore need to be subject to different, appropriate and explicit validity assessments and associated ‘airplay’. These considerations are in keeping with the appeals from a succession of authors calling for a broadening of our thinking about what constitutes robust knowledge and knowledge production especially in relation to how we might address the complexity and contextualisation of issues in society (Funtowicz and Ravetz, 1993, Gibbons et al., 1994, Nowotny et al., 2001). All of which echo Jantsch’s (1972) calls decades earlier for purposive change, and insight that purposive intent can and should be reflected in the juxtapositioning of disciplinary knowledges, thereby influencing new knowledge creation.

3.4 Mutual and Transformational Learning

For transdisciplinary research intending to create change, extending impact beyond the life of a project is essential. Therefore, collaborators should come away with new perspectives, new orientations, new strategies, and new tools – seeing and doing things differently as a result of their experience of transdisciplinary research. That means the process has to value and trigger learning for researchers and for those engaged in projects, and to provide just the right amount of the right kind of cognitive dissonance to facilitate a transformational learning experience (Taylor, 1998). The primary attribute of this outcome space of mutual and transformational learning is deeply reflective practice on the part of everyone involved: researchers, collaborators, and participants.

Richer conceptions of learning comprise both a 'what' and a 'how' (Marton and Booth, 1997). In this element of the transdisciplinary research outcome spaces framework, learning 'what' is 'transformational' and learning 'how' is 'mutual'. This characterisation is broader than most articulations of learning in transdisciplinary research. It ranges across two of Klein's (2013) 'clusters' of current meanings in transdisciplinarity: mutual learning, which she situates within 'participation and collaboration', and transformation, associated with the 'transgressive imperative'.

Mutual learning is context-dependent and occurs through social interaction by the range of collaborating partners with different expertise and knowledge involved in the process to jointly contributing to improving the situation through transdisciplinary research. Learning in this sense is a process that collaboratively generates new rich insights that remain undetectable from a single disciplinary or purpose-less (in Jantsch's terms) perspective.

The social aspect of learning in transdisciplinary research draws attention to the interactions, communications and relations amongst actors and the quality of dialogue leading to collective definitions and accommodations in terms of both the nature of the situation to be addressed and the means of determining desirable and feasible pathways. It is the experience of the collaborative, coordinated research endeavour that provides the enabling environment for the depth of reflection associated with deeper conceptual change. This kind of learning can occur at group, community, or societal scales.

The kind of learning sought in this outcome space has less to do with a particular school of learning theory, and more to do with the ultimate purpose. That is, it is concerned only with the highest levels of learning. Scholars across the diverse epistemologies within learning and including those involved in the original articulations of transdisciplinarity (e.g., Piaget, 1972) have articulated levels of learning. From a developmental perspective, this kind of learning aligns with the concept of 'transformative learning' (Taylor 1998), 'changing as a person' from a phenomenographic perspective (Marton and Booth 1997, p.38), 'triple loop' learning from a reflective practitioner perspective (Schön, 1987), 'deep' learning from a constructivist perspective (Prosser and Trigwell, 1999) and so on. Transformative, higher order, 'conceptual', 'generative' learning involves changes in norms and values, redefining goals that govern the decision-making process, reviewing and adjusting problem definitions (or perceptions of real-world situations), strategies, and actions of organizations and individuals involved. Transformational learning as defined in this framework denotes learning that leaves a legacy and contributes to changing the situation.

Whilst change within a shorter-term project situation may be possible with short-term shifts, creating change towards sustainable futures requires persistent change in both cognitive and behavioural realms. Persistent change is associated with these higher order, deeper, levels of learning that enable new perspectives and open up new possible paths. Shifts of this kind require a supportive organisational culture – one that values experimentation and 'learning from failure' (see Fam et al., 2013).

To sum up, mutual learning is significant because it requires the development of an appreciative stance towards difference. In purposive transdisciplinary research, the focus of mutual learning is the process that will help to build the kind of systemic, reflexive capacity in society that is necessary to respond to societal challenges like climate change (Ison, 2010). Transformational learning is significant because it has the potential to result in the participants involved in the process doing things differently. In these ways, learning is complementary to the knowledge element of the outcome spaces framework – it is the other means by which a project's influence extends beyond the bounds of the project itself.

4 The Outcome Spaces in Practice: Tensions and Permeability

While clearly distinct, the three outcomes of situation, knowledge, and learning, are closely intertwined in practice, leading in certain circumstances to friction, tension, permeability, magnetism and repulsion between and across these spaces. In practice, the size/importance/significance/impact of each outcome space may vary depending on contextual circumstances such as client priorities, the configuration of the project team, funding sources and arrangements and agendas (see Table 1 for further details).

In particular, one of the primary tensions in adopting the outcomes spaces framework in practice relates to allocation of scarce resources. Many authors have identified the additional resources and time required by transdisciplinary research (Lang et al., 2012, Stokols, 2006, Miller et al, 2008, Holm et al, 2013). Therefore time spent on one outcome space takes already strained time and resources away from other outcomes. Because transdisciplinary research projects involve broad types of participants,

preferences and biases toward a particular type of outcome will also be diverse. For instance a transdisciplinary project trialling alternative sanitation systems in Sydney involving industry, government and academic partners (see Mitchell et al., 2013) found many of the academic partners were strongly influenced by the “politics of research” (Altman, 1995): they were driven by the need to fulfil expectations of their academic institutions and to publish research at the expense of spending time engaging in the process of the research itself. That is, there emerged a tension between the outcome spaces of contributions to stocks of knowledge and the situation. For doctoral students engaged in purposive transdisciplinary research, there are particular tensions associated with the need to demonstrate adequate contributions to knowledge whilst wanting to create change (see Willetts et al., 2012)

Permeability between the outcome spaces is important where engaging in the situation provides an opportunity for timely contributions to the stocks and flows. Academic knowledge artefacts, such as journal articles and theses, can take years to be published, while the ‘real-world’ context may change at a more rapid pace. As a result, research findings that have the potential to influence the situation need expression through other avenues and artefacts in order to be harnessed. In the case of a recent transdisciplinary PhD which exposed the emerging global challenge of phosphorus scarcity (Cordell, 2010), the first journal article took 942 days to be published (Cordell et al., 2009). During this waiting period, the price of phosphate rock suddenly spiked 800%, creating a narrow ‘window of opportunity’ to communicate the research findings to key stakeholders within agriculture, the fertilizer industry, sanitation and the media. This opportunity led to co-founding the Global Phosphorus Research Initiative (GPRI) (www.phosphorusfutures.net) as a complementary and public means to raise awareness and engage policy-makers, industry and the public in the debate on the pressing issues surrounding phosphorus scarcity for food security. The impact of the GPRI is exemplified by a senior staff member in a North American Ministry noting the impact on their State’s new phosphorus legislation: “*This is a very modest start for [our State] with respect to phosphorus security but a big shout-out to you and your colleagues - you have begun to influence public policy development half way around the world in a tangible way*”.

5 Implications for Practice: Mutually reinforcing value and impact

The proposed framework has the capacity to provide significant value across diverse realms, including research managers, researchers, research participants, and indirect beneficiaries in the situation at large. Firstly the outcome spaces framework has the potential to significantly influence the full lifecycle of transdisciplinary research i.e., conception, design, conduct, and evaluation. Decisions taken up front for the outcomes sought in these three spaces become mutually reinforcing as the work progresses, and provide a framework for research process decisions throughout the project. For example, taking the purpose of improving the situation into account at the conception stage influences who is engaged in the research process and how they are engaged. Taking into account the outcome of providing mutual and transformational learning experiences for researchers and participants, with the goal of creating opportunities that enable related situations to be approached differently in future, has profound implications for how the situation is defined, what constitutes an improvement, how the research process unfolds, and what is viewed as valuable. Taking a broader perspective on the stocks and flows of knowledge requires different and varied kinds of outputs, impacting on the research process through key decisions about representation and validity.

Secondly, the framework offers a new way of revealing, categorising and articulating the impact of the research – a challenging task (Roux et al., 2010). Revealing impact in this way, through a new language to describe different kinds of impact, have implications across the research spectrum. The most obvious implication is its contribution to the conversation about how to broaden research assessment in practice beyond scholarly publications.

Thirdly, making the range of outcomes explicit ahead of time, and allowing that explicitness to inform the process provides new entry points for research collaborators to the research process. These entry points and experiences have the potential to shift collaborators’ expectations and understandings about research and its value outside the academy. That is, research is sometimes seen as something veiled, highly structured and rather rarified that happens only in universities. Removing the veil, providing experiences of exploration and experimentation, appreciation of diverse insights, etc. provides a practical means of enabling shifts at multiple levels, from valuing organisational learning (Fam, 2013) to opening up the contractual project management process beyond instrumental milestones.

An example illustrates how this has worked in practice, demonstrating the influence of the combination of a transdisciplinary approach and the outcomes spaces framework. A water utility approached ISF to

partner with them for an industry research grant around the economics of water recycling. The utility wanted to show that recycling is expensive and therefore others should pay. We vacillated over whether to engage, because our normative view is that other responses are possible. We decided to accept the invitation to lead the project. We invoked the outcome spaces up front. Our intention (to improve the situation) was to broaden the conversation around the costs, benefits, and risks of recycling with a view to improving the transparency and integrity of investment decision-making and improving the equitable distribution of costs, benefits, and risks. To improve the situation, we introduced the idea of capturing 'stories' (unusual in the water sector) as well as quantitative data in terms of costs (i.e. requiring mixed methods) seeking to reveal real costs, benefits, and risks in practice. To contribute to the stocks and flows of knowledge, we eschewed the granting body's request for a 'final report', and instead proposed multiple, short, highly engaging outputs. To begin the process of mutual and transformational learning, we invited all the other significant classes of stakeholders [with quite different views from the utility] to join the research (11 new partners: councils, land developers, technology suppliers, retailers, regulators).

In terms of the conception phase of research, the outcome spaces framework had profound influence. Because we were thinking about what change we wanted to see in the situation up front, we invited in to the process all the other significant stakeholders and facilitated a conversation amongst a group that had not previously come together. That conversation shifted the boundaries of the work up front – from identifying who should pay and how much, to an investigation of what could be learned from experience about how else success might be assessed and decisions made, and what had been the real triggers in practice for investment decisions. In terms of research design, the situation outcome of broadening the conversation meant that we chose a research methodology that would span the professional and personal epistemologies of people in the sector: a mixed methods approach to historical in-depth case study that would give confidence through including e.g., expenditures as they were actually incurred, but also a focus on stories, because of our experience of, and the evidence for stories as a powerful means to shift perceptions (Parkin, 2004). Paying attention to the mutual and transformative learning outcome space with our original partner and 11 new partners meant bringing them into the process of research design, together agreeing on this approach, and then together creating the process (criteria, trade-offs) for deciding on case study sites, and for identifying emerging cross-cutting themes.

The outcome spaces framework becomes mutually reinforcing. For example, the decision not to produce a conventional report, but rather to produce a series of concise, highly visual, case study outputs designed for immediate engagement and use, also influenced the number of case studies it was possible to engage with at the appropriate depth. The intention to facilitate mutual and transformational learning for all those involved in the project, including those we interviewed, influences the research design through the trade-off between number of case studies and number/depth of interviews for each case study – our clear preference was for a more complete range of perspectives from a smaller number of case studies, over increasing the number of case studies at the expense of the depth and richness of the stories we could elicit.

The intention to improve the situation through broadening the conversation and the commitment to mutual and transformational learning both mutually reinforce the form of the knowledge outputs as implementation of the research proceeded. We adopted a weaving metaphor to ease engagement with the 16 deliverables, and developed a graphic to show how the six cross-cutting themes emerged from the eight rich and deep case studies, and how reflection on and learning from that whole package is what underpins both the policy piece and the guidance materials, deliberately subtitled 'Shifts Happen', because the principal insight from the study is that things change, and the principal risks in recycled water are not in the technological delivery of a guaranteed quality of water, but rather in the plethora of realms that surround the technology. (For the detailed image on the concept of weaving to depict the relationships between deliverables see: <http://waterrecyclinginvestment.com>).

At the same time as this project, a leading economics firm engaged in the water sector proposed a quite different (disciplinary, conventional design) response to the same industry research fund – they sought to extend the application of cost benefit analysis for recycling by developing a water specific framework and conducting economic valuation studies (hedonic pricing, willingness-to-pay) to provide values for inclusion in the framework. In contrast, six of the eight case studies in our project would have failed a conventional cost benefit assessment, but are considered successful investments by key stakeholders because of the other values they provide – the opportunity for a water utility to learn by doing what recycling means for their business, or providing a secure water supply for the dominant agricultural activity that underpins the socio-economic resilience of an entire region. In other words, the economic rationalist research response seeks to answer the 'how much and who' question, whereas the

transdisciplinary outcome spaces response seeks to show the validity of a different path, and provides a practical, defensible means of broadening and making transparent the investment decision making process.

6 Conclusions

Beginning at the end, that is, starting with a richly articulated picture of where we would like to be at some defined point in the future has powerful consequences for any human endeavour, not least for transdisciplinary research. Early conceptions of transdisciplinarity included a strong role for 'purpose', seeing it as the way to bring meaning to transdisciplinary endeavours. Whilst some have retained this notion in their praxis, many have implicitly eschewed it in favour of more objectivist approaches. This paper has proposed a framework to tease apart the qualitatively distinct but overlapping and interrelated set of outcomes associated with purposive transdisciplinary work i.e. research projects that explicitly seek to create change, for example, towards more sustainable futures. The framework consists of improvements to the situation, contributions to the stocks and flows of knowledge, and enabling mutual and transformational learning for both participants and researchers. Bringing these three 'outcome spaces' into focus has been shown to have profound implications across the lifecycle of purposive transdisciplinary research, impacting on who is involved, how the research is designed/conducted/evaluated, what is included/excluded, and even why the research is undertaken. This kind of work has a particular epistemological and ontological orientation. Improving our capacity to be explicit about these orientations and their implications for our processes will improve our capacity to communicate across the divides and diversity within the transdisciplinary research community and beyond.

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