

DISCUSSION DOCUMENT: TOWARDS INTER- AND TRANSDISCIPLINARITY AT NELSON MANDELA UNIVERSITY

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Updated 25 June 2024

1. Introduction

In the knowledge society, universities are regarded as vital sources of new knowledge and innovative thinking, providers of highly skilled personnel and credible credentials, contributors to innovation, and agents of social justice and mobility (LERU, 2008). Academic institutions remain organised along disciplinary lines, which has resulted in excessive specialisation with countless disciplines and specialties in different knowledge areas. However, complexity science is gaining strength and attaches value to dialogue between the natural sciences, engineering, technology, humanities, and the arts. Inter- and transdisciplinarity refers to the university's intention to review the paradigms, theories, methods, and process of constructing the knowledge it produces (Andalecio, 2009: 83).

Castells (2000: 693) argues that contemporary universities face challenges such as discontinuous change, emergent over-prescribed order, simultaneous attention to local and global concerns, and the growing dominance of networks. Addressing sustainability challenges demands cooperation between specialists with diverse backgrounds to bridge knowledge divides within universities, and between scientific communities and broader society. This requires the spanning of knowledge boundaries to foster collaboration and integration across disciplines (Guston, 2001). While intentionally creating spaces for academic communities to engage with different publics is laudable, it is essential to enhance conceptual clarity of the rationale for and challenges associated with multi-, inter-, and transdisciplinarity.

2. Conceptualising multi-, inter- and transdisciplinarity

Moore (2011, 599) asserts that it is precisely through distinguishing among different forms of multi-, inter-, and inter- and transdisciplinary practices that we uncover the potential for creativity and innovation such disciplinary border crossings may afford. A continuum of increasing relationships between disciplines can be measured along three dimensions. A low degree of openness, interaction, and integration is typical for disciplinarity, while a progressive integration of knowledge is a feature of multi-, inter-, and transdisciplinarity.

Multidisciplinarity refers mainly to a sequential analysis of a problem by disciplinary experts with few interactions between them. Growing interactions and efforts to integrate disciplinary insights lead to interdisciplinarity, with added value for the participating disciplines. Finally, in transdisciplinarity, interactions are extended beyond the academe to solve societal problems in integrated ways that draw on the knowledge of multiple actors (LERU, 2017: 12).

An overview of the definitions of various forms of knowledge production is outlined in Table 1 below.

Table 1: Overview of definitions

Disciplinary	Takes place within the boundaries of currently recognised academic disciplines, while fully appreciating the artificial nature of these bounds and the fact that they are dynamic. The research activity is oriented towards a specific goal, looking for an answer to a specific question.
Multidisciplinarity	Involves different academic disciplines that relate to a shared goal, but with multiple disciplinary objectives. Participants exchange knowledge, but do not aim to cross subject boundaries to create new integrative knowledge. The research process progresses as parallel disciplinary efforts without integration.
Interdisciplinarity	Involves several unrelated academic disciplines in a way that compels them to move beyond disciplinary boundaries and paradigms. Discipline experts synthesise disciplinary knowledge to create new knowledge to achieve a common research goal.
Transdisciplinarity	Involves researchers from different disciplines and stakeholders beyond the university to co-create knowledge that addresses complex societal challenges.

Source: Tress *et al*, 2004: 488

To build on this conceptualization, the levels of collaboration and integration between disciplines can be categorised as follows:

- *Multidisciplinarity* – is the lowest level of integration and draws on knowledge from different disciplines which remain within their boundaries, without any of the disciplines being modified or enriched by this interaction (Toomey et al, 2015: 1). Multidisciplinary research draws on the separate contributions of more than one discipline. Investigators may share facilities and research approaches while working separately on distinct aspects of a problem.
- *Interdisciplinarity* – involves cooperation among various disciplines where there is mutual enrichment and reciprocity in their interchanges (Andalecio, 2009: 84). Interdisciplinarity seeks to synthesise links between disciplines into a coordinated and coherent whole. Interdisciplinary research is often connected with applied research that uses different disciplinary perspectives and methods to solve real-world challenges (Toomey et al, 2015: 1).
- *Transdisciplinarity* – is the highest level of integration (Andalecio, 2009: 84) in that it moves beyond cooperation between disciplines and represents knowledge generation that transcends disciplinary, academic, and epistemic boundaries (Thompson et al, 2017: 30). As the prefix "trans" indicates, transdisciplinarity concerns that which is at once *between* the disciplines, *across* the different disciplines, and *beyond* all disciplines. Its goal is to understand the present world through the unity of knowledge (Nicolescu, 1997).

Transdisciplinarity refers to activity that transcends disciplinary boundaries in the integration and synthesis of content, theory, and methodology from various disciplines in producing new knowledge (Russell, 2005: 35). Transdisciplinary work moves beyond the bridging of divides within academia to engaging directly with the production and use of knowledge outside of the academy. In this approach, societal impact is the central aim of the research. Solutions emerge from an action-oriented process built on direct collaboration with the groups involved (Toomey et al, 2015: 1).

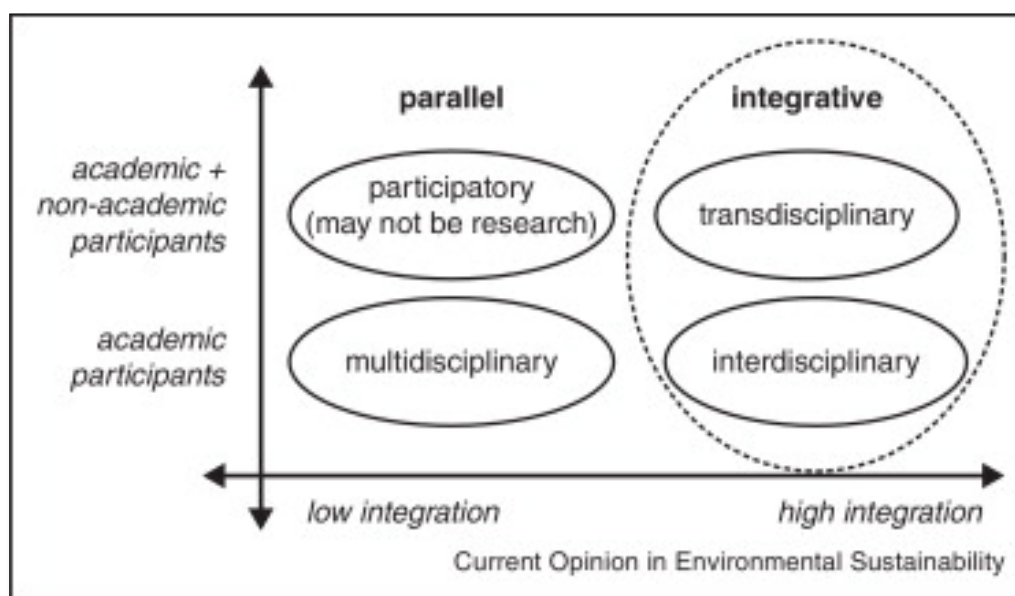
In transdisciplinary research, the primary focus is not on the disciplines but on the generative and integrative potential of the interaction of individuals from different disciplines working together with various stakeholders from a variety of non-scientific knowledge domains (Moore, 2011: 600; Esler et al, 2016: 3). This is supported by Düspohl et al (2012) who assert that the core of transdisciplinary research is the generation and integration of knowledge through the participation of all relevant disciplinary experts and stakeholders within and beyond the university.

“Strong” transdisciplinarity as described by Max-Neef (2005) creates a distinct, emergent, and shared conceptual reality and language that draws upon the perspectives of its contributing disciplines. Integrative transdisciplinary research includes the involvement of various academic disciplines, policy, and society in defining research problems, appreciating different types of knowledge, and achieving integration as a precondition for solving problems affecting interacting human and natural systems.

Although specifics vary, knowledge integration categories extend from those marked by relative independence of investigators and specialised disciplines to those that are deeply integrative, coordinated, and transformative; span disciplines; and include stakeholders throughout the effort, from question formulation through to data gathering, interpretation, and application (Morton et al, 2015). By bridging disciplinary divides and extending the ‘right to do research’ to marginalised communities, a key feature of these processes is reflection (Toomey et al, 2015: 2).

According to Tress et al (2004: 488), the strength of integration and stakeholder involvement varies across research concepts, from low to fully integrated. As illustrated in Figure 1 below, transdisciplinarity represents the integration of values and knowledge from society into the production of scientific knowledge. In contrast to multi- and interdisciplinarity, it does not limit itself to linking different scientific or disciplinary paradigms, but also integrating stakeholder knowledge and values.

Figure 1: Degrees of integration and stakeholder involvement in integrative research



Source: Tress et al, 2004: 484

Inter- and transdisciplinary research is relevant to the two main types of research practice at universities, namely, ‘basic research’ which seeks to generate knowledge for its own sake, and ‘applied research’ which aims to address questions of societal relevance. These two modes should be conceived as a knowledge generation continuum, with inter- and transdisciplinarity highly relevant to both modes (LERU, 2017: 18).

By combining the distinction between disciplinary and inter- and transdisciplinary research and between basic and applied research, it is possible to delineate four types of research profiles as depicted in Table 2 below.

Table 2: Four types of research profiles

	Basic	Applied
Disciplinary	Drives discovery of fundamental knowledge in a highly specialised discipline	Develops specialised practical applications to enhance the practice in a professional field
Inter- and transdisciplinary	Brings new questions, models, and methods to their discipline by grasping what is happening in other disciplines	Works at the interface between science and policy to deal with complex problems

Source: LERU, 2017: 19

Universities need to balance these complementary profiles and make them work together. Put differently, disciplinary basic research has been the dominant mode in academic institutions, but there is also a need to support research capacities in the other three quadrants (LERU, 2017: 18).

This paper will focus on the rationale for, challenges experienced with, and systemic enablers for inter- and transdisciplinarity as the highest forms of integrative knowledge generation to address complex, socially relevant challenges.

3. Rationale for inter- and transdisciplinarity

The increased uncertainty and connectedness of contemporary societies and the centrality of knowledge to well-being and sustainability require new modes of knowledge generation. The innovation and creativity that drive transdisciplinarity are key to creating social value. Navigating the tensions of working across disciplines, traversing boundaries of practice and theory, and working collaboratively with communities, is the source of re-invigorating the university (Moore, 2011: 607). Similarly, Wilson (1998: 8) argues that joining up knowledge across disciplines to create a common groundwork of explanation is the most promising path to innovative advancement, intellectual adventure, and human awareness that leads to the most significant scientific breakthroughs.

As both depth and breadth are important for the progression of scientific knowledge, the increasing compartmentalisation of science has become an obstacle to addressing complex global challenges. High levels of complexity within finite planetary boundaries require inter- and transdisciplinary approaches that the dominant strain of disciplinary science has been ill-equipped to provide (LERU, 2017: 7).

Peters (2017: 385) characterises “wicked problems” as “...complex, involving multiple possible causes and internal dynamics that could not assumed to be linear, and have very negative consequences for society if not addressed properly”. Such problems are difficult to define, involve multiple actors, are socially and politically complex, and have no clear solution thus requiring an approach that transcends traditional disciplinary perspectives (Peters, 2017: 386; Miller, 2016: 45). Wicked problems cannot be viewed in isolation but all associated problems, both in space and time, need to be recognised and considered together.

There is a growing awareness that multiple disciplinary viewpoints are required to address “wicked problems”. Collective sense-making of the problem and a shared understanding of possible solutions by the various stakeholders are the source of sustainable solutions (Andrew, 2013). Transdisciplinary research addresses these problems through “...a process that integrates a variety of disciplines and actors...with the aim of developing knowledge and practices that promote what is perceived to be the common good” (Pohl & Hirsch Hadorn, 2007: 16).

An expansion in transdisciplinarity has also coincided with the broader social distribution of knowledge in increasingly educated societies. Specialised knowledge is no longer only the domain of academic elites, but is in demand from the public, government, non-government organisations, and industry. Knowledge restricted in its use by elite, specialised groups, rather than being broadly communicable and accessible, has less value (Russell, 2005: 36).

It is equally important for universities to equip graduates in these integrative approaches to enhance the capacities of governments, the private sector, media, civil society, and other societal actors to apply them at all levels of society. However, university curricula and qualifications largely continue to reflect disciplinary silos. The disciplinary divide in universities, especially between the natural and social sciences, persists and leaves graduates unprepared for an interconnected and dynamic world (Esler et al, 2016: 5).

The atomistic or reductionist approach to problem solving that is characteristic of single disciplinary approaches typically favours one perspective over others and often generates unintended consequences that create more problems. A paradigm shift is currently underway that acknowledges different classes of problems, some of which require a multi-level approach and the integrated perspective of multiple disciplines (Miller, 2016: 36). Benefits associated with inter- and transdisciplinary research include an ability to view issues from different conceptual frames, formulate novel perspectives, stimulate transformative learning that advances knowledge production, and form new networks to enable broad knowledge sharing (Esler et al, 2016: 4).

Inter- and transdisciplinary thinking are rapidly becoming an integral feature of research due to powerful drivers, such as the inherent complexity of nature and society and the need to solve societal problems and questions not confined to a single discipline (Facilitating Interdisciplinary Research, 2005). The development of models whereby disciplines collaborate to provide new understandings of pressing problems has become scientifically possible on a larger scale and societally necessary as a more systematic endeavour and intellectual project (LERU, 2017: 8).

Weingart (2015: 8) differentiates between mutually reinforcing 'internal' and 'external' factors that have contributed to the rise of inter- and transdisciplinarity, namely:

- Internal developments within disciplines that lead to their cooperation or fusion.
- Strategies of universities in response to financial and political incentives that encourage internal structural re-arrangements.
- External developments, such as demands for 'value for money', innovation, and improved technology transfer.

Inter- and transdisciplinarity acknowledge the value of disciplinary traditions in research while also recognising the significance and legitimacy of knowledge claims that go beyond disciplinary norms (Moore, 2011: 600). Nicolescu (1997) asserts that the emergence of transdisciplinary knowledge implies a necessary multidimensional opening of the university to the broader society within which it is situated and to other sites of knowledge production (such as private institutions and laboratories, industrial companies, and non-profit organisations).

Inter- and transdisciplinarity offer opportunities to construct a synthesis of knowledge systems that can develop actionable science to address socially relevant issues affecting complex human and natural systems through the interaction between scientists, stakeholders, and other professionals. Since reality is diverse and cannot be understood by focusing only on its parts, there is a demand for the establishment of a collective intelligence facilitated by the cooperation of specialists from various disciplinary fields (Andalecio, 2009: 85).

Individuals may engage in inter- and transdisciplinary collaboration because they believe it will enhance their ability to compete for funding, generate impactful research findings, or contribute to society. Those who have participated in successful inter- and transdisciplinary teams consistently report that the most compelling outcome is the intellectual stimulation and creativity generated by the collective group. Individuals consciously or unconsciously compare the perceived benefits (e.g., funding, recognition, and intellectual creativity) and costs (e.g., time, effort, and resources) of participating in inter- and transdisciplinary research. Although the perceived benefits may be high and the costs low, researchers may still choose not to collaborate. Understanding that this is the case and that it takes time for shared conceptualisations of the problem to emerge is crucial to the success of inter- and inter- and transdisciplinary research teams (Pennington et al, 2013: 567).

While real-world problems often require an integrative approach, Gaziulusoy et al (2016: 61) point out that transdisciplinary research poses several challenges, which they have grouped into four categories, namely:

- **Inherent challenges:** directly arise from the characteristics inherent to transdisciplinary research such as the need for project leadership to manage the complexities associated with fostering cross-functional collaboration to facilitate the co-creation of knowledge.
- **Institutional challenges:** emerge from the traditional institutional structures and processes, such as career development and resource allocation, which incentivise traditional disciplinary modes of knowledge generation.
- **Teamwork challenges:** stem from the need to foster collaboration between researchers from different disciplinary backgrounds and with societal stakeholders in ways that generate scientifically rigorous and socially relevant transdisciplinary knowledge.

- **Emergent challenges:** are unexpected, beyond the control of research teams, and do not relate directly to the university although they have a prominent impact on institutional and project dynamics. These challenges include those relating to the political environment, external funding, and stakeholder engagement. Emergent challenges need to be mediated by project leaders through adaptive strategies.

Given these challenges, it is important to design systemic enablers that facilitate inter- and transdisciplinarity.

4. Systemic enablers for inter- and transdisciplinarity

While inter- and transdisciplinarity have achieved recognition, they have not reached their full potential due to the persistence of significant obstacles at many levels. Academic institutions have evolved from communities of peers sharing the same background and interest in academic disciplines, which have become sophisticated social systems to produce new knowledge, based on stringent quality criteria (LERU, 2017: 6). Researchers whose positions are grounded in disciplinary departments who seek to transcend disciplinary boundaries, particularly in areas outside those prioritised by their institution, may therefore still meet a variety of institutional obstacles (Russell, 2005: 37).

Esler et al (2016: 4) note that, in South Africa, the academe is dominated by a highly competitive, disciplinary approach, which tends to separate research and education from problems and issues of everyday practice. This is exacerbated by constrained financial resources and pressure to supervise more postgraduate students. This favours disciplinary research with a limited understanding of the societal context and an avoidance of addressing complex transdisciplinary challenges.

Further structural challenges impacting inter- and transdisciplinary connections and integration include the capacity of researchers to link different conceptual frameworks to allow creative synthesis across disciplines from problem formulation to execution and application. In addition, transdisciplinarity requires effective collaboration across space and time, and intentional efforts to involve societal stakeholders to ensure that the research outcomes are actionable (Morton, Eigenbrode & Martin, 2015).

Inter- and transdisciplinarity require significant investment and commitment within a higher education system primarily designed for disciplinary research. Institutional barriers include:

- Difficulty publishing inter- and transdisciplinary research due to an uncomfortable fit within traditional disciplinary journals.
- Establishing the right trade-off between disciplinary depth and interdisciplinary breadth.
- Perceptions that interdisciplinary research is academically inferior to disciplinary research.
- Giving insufficient academic recognition and rewards for inter- and transdisciplinary research.
- Interdisciplinary researchers can experience career limitations (Esler et al, 2016: 4).

Dedicated attention should thus be devoted to finding the right balance between preserving the disciplines while encouraging inter- and transdisciplinary collaboration. The overarching strategic intention should be to support both disciplinary and inter- and transdisciplinarity as mutually reinforcing in solving intractable, unprecedented scientific and societal challenges (LERU, 2016: 3-4).

Recognising the challenges of working at the science-action interface is crucial to the success of transdisciplinary partnerships. Enabling actions for building successful transdisciplinary partnerships include the following: (a) explicitly addressing the science-action gap, (b) putting in place enabling organisational preconditions, (c) assembling a functional well-structured team, and (d) actively building interpersonal and individual collaborative capacity. These enabling actions operate at different levels, which are nested within one another from the level of the individual to the team and intra- and inter-organisational levels (Cockburn et al, 2016).

Boon, Horlings and van den Besselaar (2012: 5-6) concur with the above by providing an overview of the individual, interactional and institutional factors influencing the effectiveness of inter- and transdisciplinary teams involving actors coming from different disciplines, normative backgrounds, and organisations. Each of these factors are briefly outlined below:

- **Individual factors** focus on the extent to which the participating actors have sufficient competencies, readiness, and motivation to collaborate with various actors. Collaborative readiness includes the theoretical and methodological flexibility to traverse disciplinary boundaries and make necessary connections and integrations.
- **Interactional factors** play a role because the team contains a wide diversity of actors, backgrounds, disciplines, and locations. Communication between team members should be coordinated and stimulated through frequent interactions.
- **Institutional factors** include the divergence in incentive systems that govern the various project partners. Of importance, is the extent to which project members are directly rewarded by the work they do in the project and whether there are any tensions between their participation in the project and their contribution to their home faculty. A second dimension of institutional factors is the nature of administrative support provided to the team to facilitate higher levels of organised interactions. The wide range of actors involved requires the alignment of financial, governance and legal arrangements.

Inter- and transdisciplinarity require high levels of interactions between heterogeneous participants from within and beyond the university. In turn, this necessitates that particular attention be devoted to the role of leadership in setting up and managing project teams in a manner that yields shared research goals, continued collaboration, and enhanced scientific reputation.

4.1 Setting up and managing inter- and transdisciplinary teams

Disciplinary differences in language, tools, work practices, epistemologies, paradigms, and goals relative to the project, requires a better understanding of the processes involved in team formation and establishing a shared understanding of the mission and objectives. If inter- and transdisciplinary teams are to deliver innovative and frame-changing solutions that can be achieved through requisite variety and heterogeneity, they must overcome the barriers embedded in singular disciplinary perspectives. This work is inherently uncomfortable as it requires openness to accepting diverse knowledge domains and ways of working that may conflict with one's own assumptions, disciplinary orientation, and work practices.

There is work to be done before, during, and after the teaming experience to assist the team in navigating the transitions from a group representing single disciplines to a unified team that

transcends individual disciplinary boundaries and perspectives (Miller, 2016: 36). Esler et al (2016: 4) concur by pointing out that it is simpler to work with colleagues in your own area of disciplinary expertise who share the same vocabulary and ingrained conceptual understanding. Inter- and transdisciplinary collaboration requires a relatively large time investment to allow for relationships to establish and for teams to evolve past initial differences in perspectives, cultures, methods, theories, and approaches. Setting up and managing inter- and transdisciplinary research projects is challenging and project leaders need to be able to bolster interactions, communication, and team building.

After the initial conceptualisation of the research problem, a first key step is to identify potential collaborators and to assemble a team of researchers. Not only does knowledge matter, but vital competencies also include interpersonal skills, motivation, being willing to contribute to the project, scientific curiosity, openness to pluralism, and a tolerance for ambiguity. The confluence of these qualities among team members shapes the potential for scientific creativity and innovation (LERU, 2017: 14).

After assembling a team, developing a common research strategy is a crucial albeit cumbersome and often overlooked step. It requires the development of a common vocabulary to reduce any communication barriers typical of inter- and transdisciplinary research. Andalecio (2009: 88) notes that creating a favourable environment for inter- and transdisciplinary studies requires criteria for excellence, innovation, and induction, covering the various areas of knowledge. Critical pluralism—adopting an open, questioning attitude to others' and one's theories and methods—is central to the success of inter- and transdisciplinary efforts. Most important is making time for researchers from various backgrounds, and for interested policy and community members, to work together in designing, conducting, and analysing research projects (Buizer et al, 2015: 679).

The importance of face-to-face social interactions for rapid communication of ideas and information, building trust, and diffusing conflict are well recognised (Morton, Eigenbrode, & Martin, 2015). Hampton and Parker (2011) report that the number of face-to-face meetings among team members is the strongest predictor of working group productivity and scientific impact. In a multi-campus context, the spatial distance between researchers located on different campuses can be barrier to collaboration. However, ways to overcome this include rotating the meeting locations, undertaking joint fieldwork, and contributing to joint publications (Buizer et al, 2015: 677).

Inter- and transdisciplinarity suggests a radical and transformative engagement that doubly disrupts the traditional academy. It not only disrupts traditional academic systems of accountability, evaluation, and reward, it also disrupts the norms and values about what constitutes legitimate knowledge, and deeply held beliefs about what we know and how we know what we know (Moore, 2011: 601).

Fruitfully integrating different disciplinary traditions to produce knowledge of value to society can be achieved by:

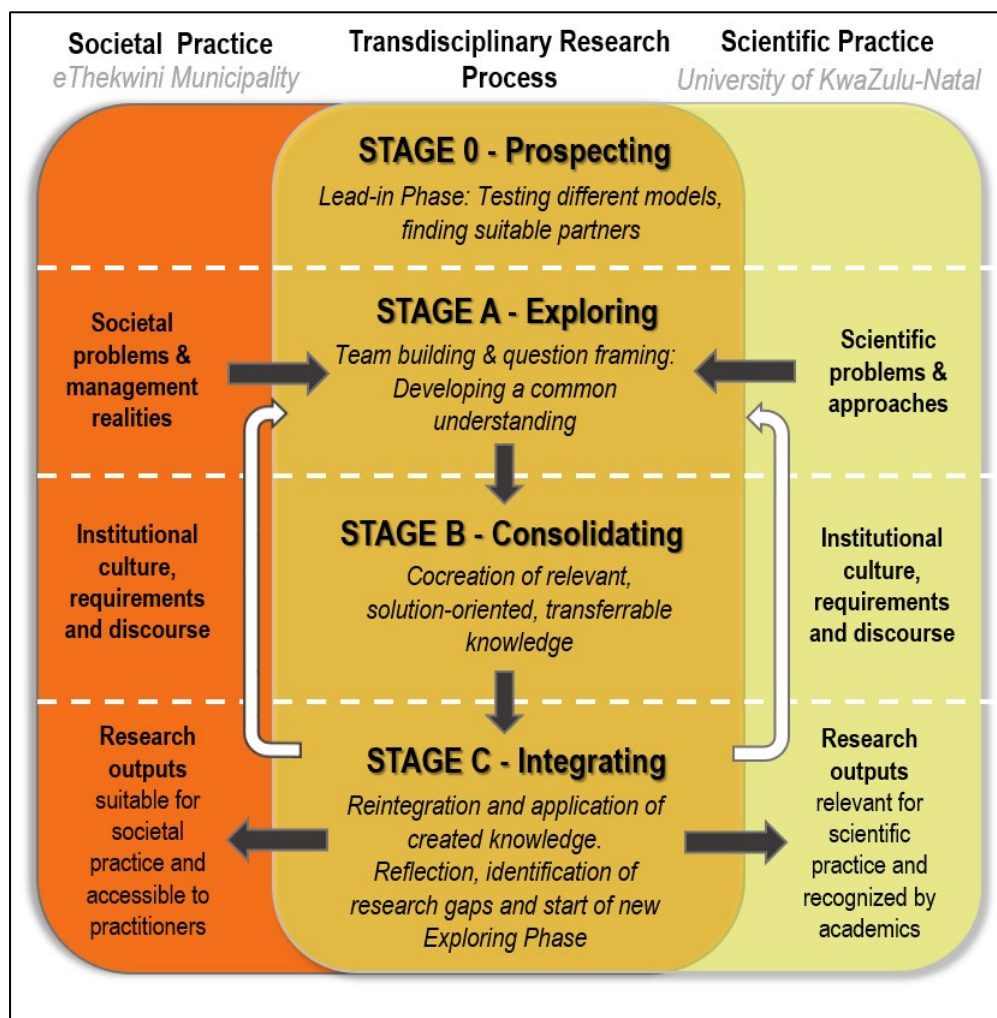
- Constituting inter- and transdisciplinary teams in ways in which members can align their competencies with the requisite research deliverables.
- Developing inter- and transdisciplinary competencies throughout researchers' careers.

- Providing clear guidelines to team members of the criteria for exemplary inter- and transdisciplinary research.
- Devoting sufficient time and opportunity for reflection into inter- and transdisciplinary research processes to build trust and to emphasise the importance of the entire process, not just the delivery of measurable outputs (LERU, 2017: 15; Toomey et al, 2015: 2-3).

Several other factors increase the complexity of team-based inter- and transdisciplinary research, including the size of the group and the diversity of its members' backgrounds. Proportional to the size and diversity of the team is the risk of misalignment between individual members' goals and the overall goals of the project. In addition, the challenge of coordination increases as high interdependence is a common feature of inter- and transdisciplinary research. These factors, along with the inherent challenges associated with novel scientific approaches, make inter- and transdisciplinarity generally longer and riskier than disciplinary research (LERU, 2017: 14).

To mitigate against these risks, Cockburn et al (2016) outline a conceptual model for the transdisciplinary research process in Figure 2 below.

Figure 2: Conceptual model of the transdisciplinary research process



Source: Cockburn et al, 2016

According to the conceptual model illustrated above, the transdisciplinary research process involves several stages, namely:

- **Stage 0 - Prospecting:** In this stage, enabling leadership, interpersonal relationships, and trust-building play an important role in building the team and laying the foundations for future collaboration.
- **Stage A - Exploring:** The “scoping” or exploratory stage requires significant time investments and regular face-to-face interactions to agree on a joint vision and broad framing of research questions.
- **Stage B - Consolidating:** During this stage, the identity, goals, objectives, research questions, and mechanisms of the partnership are formalised and refined. Team assembly is consolidated through the appointment of project leaders who remain directly involved in the oversight and strategic direction of the partnership. A multi-stakeholder steering committee closely manages budgets and implementation.
- **Stage C - Integrating:** The goal during this stage is to ensure that research outputs are integrated successfully into decision-making and management, and that these are based on jointly formulated research questions. This stage also includes an evaluation of the research process.

Key to all these stages is the role of project leadership in creating a nurturing environment that establishes “rules of engagement” that cultivate mutual respect and trust. Such an environment facilitates the alignment of research goals with competencies and team responsibilities through a commonly developed framework (LERU, 2017: 14).

Inter- and transdisciplinarity involve a shift in values and attitudes to reframe the problem, a willingness to accept diverse epistemologies, and an openness to consider multiple solutions. Each transition requires a change in the level of investment by each team member. In the case of inter- and transdisciplinarity, all members must be willing to subordinate their disciplinary perspectives to achieve a common vision. Failure to recognise the formidable disciplinary and cultural differences places the teams and their projects at risk (Miller, 2016: 39).

Cockburn et al (2016) provide an overview of key factors required in assembling high-functioning transdisciplinary partnerships. These include the following:

- **Enabling leaders**
 - Leaders establish the structures and conditions for the complex system to creatively solve problems, adapt, and learn (Galuska, 2014: 35). This requires establishing a compelling vision for the future, valuing diversity, and connecting people with diverse perspectives and ideas to facilitate collaboration.
- **Institutional champions**
 - Wale, Chishakwe, and Lewis-Lettington (2009: 6) refer to the ‘3M modus operandi’ to describe transdisciplinary projects that are ‘multi-stakeholder’, ‘multi-disciplinary’, and ‘multi-sectoral’. They recommend a ‘task force’ structure as the preferred or most convenient mechanism to apply the 3M concept.
 - Task forces are standing committees drawn from participating institutions and hosted by an institution, called the process leader. They are constituted by a cross-section of stakeholders,

disciplines, and sectors, with the host and the individual or institutional members all being agreed upon at an inception workshop.

- The diverse representation of stakeholders, sectors, and disciplines in a participatory research process is crucial since it provides legitimacy to the outcome of the process, balances inherent competing interests, and enables the identification of researchable questions from multiple perspectives (Wale et al, 2009: 10).
- **Brokers or boundary spanners**
 - Long, Cunningham, and Braithwaite (2013: 1) refer to the important role of brokers and boundary spanners in facilitating transactions and the flow of information between people or groups separated by some gap or barrier such as geographic location or differing disciplines or professions.
 - Networks are increasingly seen as an optimal structure to organise clusters of diverse individuals, groups, or organisations who aim to work together collaboratively.
 - Brokers can facilitate access to novel information, or resources, facilitate transfer of knowledge, and coordinate effort across the network. Boundary spanning as a form of brokerage includes the idea of crossing organisational or cultural boundaries to exchange knowledge or mediate interactions.
 - Brokers serve as conflict resolvers in transdisciplinary teams to span the boundary of mismatched knowledge, paradigms, and experience between scientists, practitioners, and other societal stakeholders. As well as pre-empting conflict by knowing what each stakeholder group does not know about the other, their familiarity with various perspectives improves trust and collaboration.
- **Content champions**
 - Among the secondary leaders, those with technical and scientific competencies directly relevant to the research goals of the partnership play an important role (Gray 2008).
- **Process champions**
 - Among the secondary leaders and support staff, it is necessary that some have competencies in leading the process and actively contributing to building bridges, facilitating learning, and ensuring ongoing evaluation and reflection (Gray 2008, Wale et al. 2009).
- **Helpful critics**
 - Research participants dissatisfied with their experience of inter- and transdisciplinary research provide useful feedback on some of the challenges they encountered in crossing traditional disciplinary boundaries.
- **Administrative support staff**
 - A shortage of administrative support staff can hamper progress and frustrate research participants burdened by project administration (Goring et al. 2014).

Managing inter- and transdisciplinary teams requires developing new working relationships and networks among these various role players.

4.2 Staffing

Despite the benefits of inter- and transdisciplinarity, Weingart (2015: 12) notes that recruitment and selection processes are determined mostly by academic departments, which results in recruitment decisions being legitimated against disciplinary 'quality standards' rather than the requisite competencies for inter- and transdisciplinary research. Thus, in most cases, inter- and transdisciplinary centres rely on the dual membership of professors and researchers within these centres and their respective academic departments. Recruiting processes should therefore not only assess disciplinary competence as the decisive criterion of quality.

Scholars or students who move into inter- and transdisciplinary areas are unlikely to find employment opportunities in universities unless they can find an inter- and transdisciplinary department or institute in their field. Similarly, existing academics may have limited freedom to move into inter- and transdisciplinary areas, constrained by undergraduate teaching requirements and potentially by departmental discipline-based research priorities. This potentially restricts inter- and transdisciplinary research to limited, short-term excursions by individual staff members, rather than to career-long and intergenerational endeavours (Russell, 2005: 40).

Russell (2005: 40) advocates for inter- and transdisciplinarity to be promoted through recruitment within the existing disciplinary structure of universities. This can be achieved by extending the idea of "free-floating" inter- and transdisciplinarity to the creation of new positions, either in programmes directed at attracting staff into inter- and transdisciplinary areas and approaches, or discretionary programmes that opportunistically create positions when talented inter- and transdisciplinary researchers are found. Administering such positions at a faculty level would allow flexibility to be maintained and may avoid competition for staff and resources between units.

Universities should not overlook the importance of developing the knowledge, skills, and attributes required to identify, frame, and address important scientific and practical problems that cut across disciplinary boundaries (Moore, 2011: 607). Inter- and transdisciplinary researchers are exposed to deep knowledge in other disciplines that they must comprehend through self-directed learning. As they grapple with the disorienting dilemma of integrating these new concepts into their mental models, these researchers think about their existing knowledge in new ways. This changed perspective enables them to generate novel research questions, envision new research paths, and apply the methods and technologies of other disciplines in new ways within their discipline. This facilitates the generation of integrative approaches grounded in multiple disciplines, thereby catalysing transformative learning that unleashes highly creative thinking, potentially beyond that which can be achieved through within-discipline discourse (Pennington et al, 2013: 570-571).

4.3 Funding and resource allocation

The distribution of funding and resources tends to operate within a disciplinary framework, and this serves as an obstacle to innovative efforts to foster inter- and transdisciplinary collaboration. Competition for and disputes over resources can result in uneven allocations of government subsidies

whereby certain disciplines and fields of study are valued and supported more than others (Irani, 2018).

Weingart (2015: 12) concurs that academic departments compete with one another for funding. Size, the amount of external funding, external reputation, and a vague perception of a discipline's relevance are condensed into an implicit ranking of stature against which inter- and transdisciplinary teams rarely have a chance to prevail when budgetary conflicts arise.

For inter- and transdisciplinarity to thrive within the disciplinary frame of the university, special consideration must be accorded to the following:

- The allocation of internal research funding and competitive grants.
- The allocation of funds and postgraduate student load.
- Access to resources for students and staff conducting research across departments (Russell, 2005: 38).

Inter- and transdisciplinary research centres often depend on external, unstable funding sources. Although longer-term funding partly depends on convincing funding bodies of the societal or environmental relevance of inter- and transdisciplinary research, the state of the economy and political will are important determinants of the sustainability of such endeavours (Buizer et al, 2015: 675).

Funding opportunities constitute key instruments to incentivise inter- and transdisciplinary research. Toomey et al (2015: 2-3) assert that inter- and transdisciplinary scholarship can be fostered by: a) allowing submissions to research funding schemes to be from more than one discipline; b) providing more funding opportunities where project outcomes can be more flexible and less defined upfront; and c) supporting early career inter- and trans-disciplinary scholars through support networks and training.

4.4 Academic recognition and rewards

Universities are constituted by long-established structures such as departments, schools, and faculties organised around disciplines that manage and control the distribution of rewards. Knowledge generation takes place within well-understood parameters and the legitimisation of knowledge claims within any field is held to be the responsibility of the disciplinary or epistemic community through which it is produced (Moore, 2011: 607).

As a result, inter- and transdisciplinarity may meet with resistance from university departments for epistemological reasons, because it constitutes an innovation that cannot be assessed based on broadly accepted disciplinary criteria of quality. Furthermore, the potential for role strain greatly increases when individual researchers are subjected to the competing demands placed upon them by different individuals and groups with whom they are affiliated. For example, academic researchers collaborating in inter- and transdisciplinary research centres can experience significant levels of role strain when the expectations of these centres diverge from those in their home departments (Parker & Crona, 2012: 266).

The mechanisms for rewarding academic work are mostly organised along disciplinary lines and can impede inter- and transdisciplinary collaboration. The functioning of disciplines is directed at acquiring scientific authority, which is associated with prestige, recognition, competence, and celebrity. In this context, the choices made by the researcher can be regarded as investments directed at obtaining recognition from peers, who are also competitors and therefore not keen to offer this recognition without rigorous examination (Andalecio, 2009: 85).

Inter- and transdisciplinary projects require different forms of appraisal that consider their unique attributes and qualities, as well as their intrinsic merits based on more than traditional academic standards. This necessitates recognising the value of inter- and transdisciplinarity, in generating new cutting-edge knowledge and promoting inquiry into multi-dimensional issues and problems (Russell, 2005: 38).

It continues to be a challenge for many scholars within the academy to gain recognition for research that crosses current departmental boundaries. The conventional disciplinary structure of the university has endured largely due to a dual institutionalisation, whereby national academic labour markets and hiring practices at universities cannot move away from the disciplinary organisation of departments without undermining their graduates' opportunities to find employment at other universities (Jacobs & Frickel, 2009: 54).

Departments make it harder for academics to push boundaries as they struggle to find new intellectual homes for ideas that do not fit neatly into disciplinary categories or cultures (Irani, 2018). University departments hire and promote faculty to meet discipline-specific teaching or research needs, adhering to a model that can inadvertently disadvantage individuals who contribute as part of an inter- and transdisciplinary research team.

In some departments, a researcher's contribution to collaborative work may not receive due recognition if s/he is not the senior or primary author or if the work is published in a specialised journal outside of the researcher's discipline. Discipline-specific jargon and journals have created silos that continue to present barriers to knowledge sharing and integration across diverse fields. Academics engaging in inter- and transdisciplinary fields may produce research outputs that do not conform to the traditional norms of the discipline evaluating them. Promotion committees and funding agencies rely on "well known" disciplinary standards in the epistemic community to recognise the value of the research (Moore, 2011: 606).

Assessment of inter- and transdisciplinary projects by traditional means and structures seems to fall short in two ways. Firstly, research across disciplines rarely satisfies the criteria and standards of the disciplines involved. Secondly, inter- and transdisciplinary research has unique, emergent qualities such as integrating different bodies of knowledge and synthesising new methods of inquiry. Inter- and transdisciplinarity require new modes of collaboration, interdependence, and synergy between researchers contributing different expertise and knowledge, which may not be explicitly considered in current assessment processes (Russell, 2005: 37).

In addition, traditional metrics of academic excellence used for recognition and promotion emphasise individual accomplishments and single or first-author publication of scientific findings. Pursuing joint

publications to foster collaboration can be problematic. The publishing paradox is that producing joint publications contributes the most to achieving inter- and transdisciplinary aspirations but the academic requirement to publish is often thwarted because joint publications take more time and are harder to publish in highly cited journals. Greater acceptance of inter- and transdisciplinary papers in journals that traditionally publish single-discipline papers would assist in addressing this barrier (Buizer et al, 2015: 678).

Successful academics or researchers new to collaboration on large-scale, inter-, and transdisciplinary projects are often unprepared for the additional time required to develop new skills to sustain such collaborative effort. Traditional academic structures may not be sufficiently willing to accommodate increased demands on time and resources that inter- and transdisciplinary projects may require. Institutional support for knowledge co-creation is frequently a particular concern among researchers, who express that in addition to the high transaction costs, transdisciplinary research deviates from traditional academic agendas, funding structures, and expectations (Thompson et al, 2017: 34). Those leading such research need to purposefully foster a culture that supports and rewards the additional effort and risk-taking involved (Morton et al, 2015).

There is often a tension between the aim to produce peer-reviewed publications and the time spent engaging with stakeholders. By targeting publishing as a familiar and comfortable path to enhance inter- and transdisciplinary dialogue, outcomes such as activating and facilitating knowledge sharing with external stakeholders may receive less attention. As a result, time spent on the joint publications must be weighed against other outcomes such as intensified interactions with external stakeholders to genuinely “co-create” and “co-implement” socially relevant knowledge (Buizer et al, 2015: 678-680).

The criteria used to assess academic work, either of students or academics, are generally based on the acceptability of the research by a disciplinary research community. By contrast, inter- and transdisciplinary research are evaluated based on the extent to which this research directly addresses the identified problem. External standards may be applied to inter- and transdisciplinary research by interested parties such as industry, policy agencies, or community groups, which could potentially lead to divergence between the criteria used by the academe and external parties to assess the value of inter- and transdisciplinary research (Russell, 2005: 38).

Thompson et al (2017: 37) concur by asserting that researchers participating in transdisciplinary projects may feel hindered by the tension between transdisciplinary values and the constraints imposed by entrenched traditional research practices and structures. This dialectical tension can play out in complex ways in practice, often resulting in traditional and transdisciplinary approaches contradictorily operating in parallel and may, in some cases, result in reinforcing traditional more ‘efficient’ modes of discipline-based knowledge production. Acknowledging that this tension exists, provides an objective lens for addressing potential conflicts and uneasy relationships that can develop if left unaddressed.

At the institutional level, there is a need to develop more appropriate evaluation procedures for inter- and transdisciplinary projects, which consider their open-ended and adaptive character. It is also necessary to design stakeholder participation mechanisms, that transform entrenched values and

practices, rather than just guiding participants through a consultative mechanism to legitimise a predefined research agenda. Collaboration between scientific experts, practitioners, and policymakers should generate and sustain collective action and participation. This requires organisational design and governance arrangements better equipped to integrate learning and experimentation to adjust to diverse challenges (Popa et al, 2015: 54).

4.5 Organisational design

Despite rhetorical enthusiasm for inter- and transdisciplinarity, its institutionalisation in universities has been more limited. Given the tendency of academic disciplines to prevail, universities need to invest in creating an enabling environment for inter- and transdisciplinary research and teaching to thrive (Russell, 2005: 41).

A systemic, non-directive approach is needed to facilitate interactions amongst people, structures, and institutional culture to ensure a facilitative and supportive environment for inter- and transdisciplinarity. According to Klein, emphasis should be placed on: *“identifying points of convergence, leveraging existing resources, building capacity and critical mass, platforming and scaffolding the architecture for a networked campus, benchmarking and adapting best practices, creating a resource bank, and institutional deep structuring of a robust portfolio of strategies aimed at programmatic strength and sustainability”* (Klein, 2009).

By reframing the challenges of accommodating inter- and transdisciplinarity as an opportunity for institutional innovation, there is potential to offer university administrators a way to demonstrate leadership by adopting a broader innovation agenda that could re-invigorate the university and strengthen its relationship with the wider community. The goal is to enable leading-edge research in emerging inter- and transdisciplinary fields to find an intellectual home within the university where discipline and department are often closely aligned. Creative strategies are required to advance this agenda and encourage emerging scholars and postgraduate students to participate in inter- and transdisciplinary endeavours (Moore, 2011: 602).

In terms of governance, a good start is to represent inter- and transdisciplinarity within the university's organisational chart and monitor the evolution of collaborations. One of the major institutional challenges is for universities to experiment with new inter- and transdisciplinary initiatives, yet manage them within and alongside existing strategic, financial, and planning processes primarily anchored in traditional disciplines.

a) Architectures of adaptive integration

The success of large, inter-, and transdisciplinary projects can be facilitated by creating an enabling environment for dynamic collaboration through designing architectures of adaptive integration (AAI) (Morton et al, 2015). AAI is defined as: *“...the explicit and implicit dynamic structures and processes that characterize collaborations among heterogeneous groups of scientists and stakeholders working to address a shared problem affecting complex systems over time”*. This collaborative architecture must be flexible and dynamic as conditions change and the project evolves.

While there is no universal formula for effective AAI, certain key attributes can serve as guidelines for accomplishing the integration required within transdisciplinary projects (see Table 3 below).

Table 3: Key attributes of architectures of adaptive integration (AAI)

Attributes of architectures of adaptive integration	Description
Goal-oriented	Achieves overall project goals, objectives, and deliverables
Disciplinary and cross-disciplinary components	Includes disciplinary sub-teams with deep expertise in specific fields and cross-disciplinary groups
Mechanisms to connect	Uses a variety of virtual and face-to-face mechanisms to facilitate communication and functions
Monitoring and adaptation processes	Possesses mechanisms for monitoring effectiveness and adjusting or adapting architecture accordingly
Defined boundaries with flexibility	Creates an open environment to encourage creativity and innovation while retaining project vision and goals
Awareness of project architectures of adaptive integration (AAI)	Encourages project-wide awareness of the AAI to facilitate self-organization, feedback loops, and adaptation

Source: Morton et al, 2015

Given that transdisciplinary projects are distinctly characterised by an overarching intention to co-create knowledge in collaboration with societal stakeholders, mechanisms to engage these stakeholders are varied and depend upon the type of project. Methods include:

- Integrating stakeholders in all stages of the research process from defining the problem to disseminating the findings.
- Providing opportunities for stakeholders to discuss a particular topic or project theme, with feedback loops to communicate how their ideas have been implemented.
- Field days and themed presentations directed to public stakeholder meetings.
- Computer software or web tools that enable stakeholder interaction in a virtual community; and
- Establishing a stakeholder advisory group with an ongoing expectation of participation and engagement (Morton et al, 2015).

Although all well-planned projects begin with an explicit organisational structure, the size and complexity of large projects preclude anticipating how project needs, objectives, and interactions will evolve as work progresses. Adaptive management allows for adjusting the project structure and management actions as knowledge of the system response improves through stakeholder feedback (Folke et al. 2005). As the projects progress, their collaborative architectures become more complex, incorporating inter- and transdisciplinary working groups to address emerging challenges and opportunities.

A networked organisational design is a fundamental prerequisite for the shared production of knowledge (Andalecio, 2009: 86). This can be achieved by establishing inter- and transdisciplinary research centres that create new trajectories beyond disciplinary limits.

b) Inter- and transdisciplinary research centres

Researchers can bridge disciplinary boundaries through inter- and transdisciplinary research centres within a matrix organisational design. There are many possible forms of coupling between departments and centres, including appointments, salary lines, distribution of indirect-cost returns, teaching assignments and course-teaching credits, curricula, and degree-granting (Weingart, 2015: 7). This structure tacitly acknowledges that each participant brings distinct types of knowledge, management and communication skills, and personal networks and relationships, and is expected to contribute them to the benefit of building the next layers of scientific innovation. Thus, the role of leadership is to maintain the focus and direction of the work while allowing flexibility to allow for the emergence of transformative ideas (Hampton and Parker, 2011: 908).

Highly connected scientific and knowledge networks are crucial for creative, collaborative thinking that stimulates innovative solutions at the frontiers of discovery (Pennington et al, 2013, 568). When this flexibility-with-boundaries approach is coupled with well-designed monitoring and feedback processes, networked teams increase their probability of contributing to project outcomes. As individual team members improve their understanding of the evolving structure, where they fit individually and as members of the whole team, they have opportunities to reinforce and expand on what is working and set aside those efforts that distract from or seem peripheral to the project. In this way, transdisciplinary collaboration creates opportunities to synthesise knowledge systems that can develop actionable science to address socially relevant issues affecting complex interacting human and natural systems (Morton et al, 2015).

The academic community must learn to accommodate “networks of practice” as more researchers divide their time between inter- and transdisciplinary centres and traditional disciplinary departments. In the current academic structure, the value of research and researcher alike is usually measured by producing new knowledge in the form of journal publications. However, information-sharing networks may often yield “harder to count” but equally important outputs such as expert inputs into public policy, popular media placements, alternative journal publications, or long-term product developments. While these opportunities often draw individuals to inter- and transdisciplinary work, they are also some of the most under-appreciated and unrewarded activities within the academe (Rhoten, 2004: 10).

While inter- and transdisciplinary research centres are becoming more common, they tend to be offshoots of academic departments. It is necessary to embrace structural configurations that encourage cooperation between staff and students, strengthen the ties between teaching and research activities, and ensure that inter- and transdisciplinary collaboration becomes the norm. Open, flexible boundaries will become increasingly important for academics and students, as emphasis within universities shifts from structure to cooperation. In this way, researchers will receive wider input and ideas, teaching staff will no longer feel excluded from higher-status research activities, and students will gain valuable experience from being part of real-life projects (Irani, 2018).

While funding is always necessary, it is insufficient to ensure either short-term viability or long-term sustainability of inter- and transdisciplinary research centres. For example, members of inter- and transdisciplinary communities may not have the experience, time, or visibility within the larger university to compete with established academic departments and faculties. This highlights the need for new models of accommodation that provide sufficient stability for inter- and transdisciplinary teams. In addition, the institution must innovate in professional and administrative support structures that encourage academic staff to participate in inter- and transdisciplinary endeavours (Moore, 2011: 604).

Jacobs and Frickel (2009: 53-54) reflect on the role of research centres in fostering inter- and transdisciplinarity. Research centers are an increasingly common feature of higher education and frequently function as intra-university “boundary organizations” (see Guston 2000) that help to bridge disciplinary divides and serve as an organisational counterweight to academic departments. Strong disciplines combined with the flexibility to create diverse research centres as needed may be an attractive organisational solution to the challenges of organising rapidly growing bodies of inter- and transdisciplinary research and knowledge.

Youtie and Shapira (2008: 1188) argue that, in recent decades, the role of universities as knowledge hubs has emerged whereby the university actively seeks to catalyse socio-economic development in its region and beyond through the knowledge it generates. This shift challenges universities to evolve new ways to exchange knowledge with industry and communities to promote innovation. To achieve this, boundary spanning becomes critical to enable the university to adopt a more panoptic view and perform discursive networking functions across internal and external interfaces.

Boundary spanning is typically required to coordinate collaboration between and integration across disciplines and beyond academia, while also managing the structure and inner workings of the university itself in service of a higher vision or goal (Parker & Crona, 2012: 273). Esler et al (2016: 5) assert that the facilitation role played by boundary-spanning individuals or structures is central to the success of inter- and transdisciplinary endeavours since they mobilise resources and provide opportunities for building trust, fostering collaboration, and bridging disciplinary divides.

However, Rhoten (2004: 9) is skeptical that inter- and transdisciplinary research centres have fulfilled their potential to span disciplinary boundaries. She contends that these centres tend to be organised around catch-all themes rather than unifying problem definitions and consequently fall short of achieving the transformative levels of inter- and transdisciplinary synthesis. While purposefully broad themes allow a certain amount of disciplinary variety, the absence of explicit project directions around which their researchers’ skills and ideas can coalesce appears to complicate rather than catalyse communication and collaboration between the disciplines. As a result, most inter- and transdisciplinary research centres tend to become a nexus of loosely connected individuals searching for intersections, rather than cohesive groups tackling well-defined problems.

Pryor and Henley (2018: 2214-2215) assert that boundary-spanning activities typically range along a continuum from the creation of safe spaces in which organisational challenges can be identified and explored (buffering and reflecting); to practices that establish new, expanded group identities

(connecting and mobilising); to practices which support the achievement of innovation and change (weaving and transforming).

The hierarchy of boundary-spanning practices is outlined below, namely:

- Buffering: To clarify group identity to create a safe space.
- Reflecting: To observe across boundaries and create space for others.
- Connecting: To create a 'third space' where two or more groups can engage on neutral ground.
- Mobilising: To move separate groups within a new shared boundary space.
- Weaving: To promote interdependence and creative thinking within a shared space.
- Transforming: To reimagine current realities and future possibilities within a shared space.

In respect of the above, it is important to note that "transforming" practices are likely to be inhibited by institutional inertia, resistance to change within the ranks of academia, and long-held disciplinary identities and silo mentalities. This can make it difficult to implement a new agenda for action that requires a new sense of shared identity and purpose beyond the boundaries of the disciplines.

Furthermore, Rhoten (2004: 6) argues that, across the spectrum of higher education, many initiatives deemed inter- and transdisciplinary are merely reconfigurations of traditional modes of work patched together under a new label. The transition to inter- and transdisciplinary consilience does not suffer from a lack of *extrinsic attention* from funders and policymakers or *intrinsic motivation* on the part of scientists, but, rather, from a lack of *systemic implementation* within universities. Universities tend to approach inter- and transdisciplinarity as a trend rather than a real transition and thus undertake such efforts in a piecemeal, incoherent manner.

This raises the important question of what types of organisational design might be more conducive to inter- and transdisciplinary research and scholarship.

c) Scientific atelier

The scientific atelier is a further innovation in higher education designed to integrate insights across disciplines and institutions, as well as research, learning, and service. This approach brings students and faculty from several disciplines together with a broad cross-section of stakeholders in problem-focused, adaptive, workshop settings. The ateliers focus on a particular research topic and produce a variety of publications ranging from academic journal articles with practical policy implications that represent a new inter- and transdisciplinary synthesis of the problem to grant proposals and policy papers.

All participants share the common goal of addressing the chosen research topic from their perspective and sharing their learning about other perspectives. Implementing an atelier in a local community induces a flow of benefits both for the academe (i.e. publications, monographs, further research) as well as societal stakeholders (i.e. new level of collaboration, knowledge dissemination, perception of own connection and responsibility for changes toward sustainability) (Zahvoyska, 2009: 61-62).

The main advantages of ateliers include:

- Building the capacity of researchers, students, and stakeholders for real-world problem-solving.

- Creating new knowledge with practical applications for both academia and society.
- Stimulating students to generate new knowledge and to prepare for future professional lives.
- Developing a new educational model integrating conventional lectures with field-based teaching and internet-based education.
- Facilitating dialogue and mutual understanding among academia and community, and stakeholders within a community.
- Improving communication, knowledge dissemination, and collaboration between academia and society (Zahvoyska, 2009: 61).

From an innovation perspective, the question is not **whether** the university can accommodate the engagement of disciplines and intellectual traditions in ways that make it possible to evolve in the university, but **how** it can be accomplished (Moore, 2011: 607). The next section devotes attention to the various systemic and institutional mechanisms through which inter- and transdisciplinarity can be fostered alongside continued support for academic disciplines.

5. Towards inter- and transdisciplinarity at Nelson Mandela University

Inter- and transdisciplinarity are driven by strong societal drivers and require adaptation and evolution. The challenge is to improve a system primarily shaped by the progressive specialisation of knowledge within academic disciplines while not jeopardising what has been the source of success for the academic world over the last two centuries. Adaptive governance and leadership are key to managing complexity, enabling emergence, and connecting inter- and transdisciplinary efforts across multiple organisational levels (Pennington et al, 2013: 568).

To this end, it is crucial that institutional strategy, governance, staffing, and funding arrangements contribute to cultivating an institutional environment conducive to inter- and transdisciplinarity.

5.1 Institutional strategy arrangements

Support for inter- and transdisciplinary endeavours can be facilitated through a cross-cutting, coordinated institutional strategy that devotes attention to the following:

- 1) Explicitly embed inter- and transdisciplinarity in university strategy to recognise the importance of inter- and transdisciplinary research, and to position the university as a place where inter- and transdisciplinary research is valued and proactively encouraged.
- 2) Incorporate inter- and transdisciplinarity in the governing structures of the university. In terms of concrete institutional arrangements, this could involve setting up a reflection group or task force within the Vice-Chancellor's office to signal support for inter- and transdisciplinary research at the level of institutional strategy.
- 3) Entrust the Deputy Vice-Chancellors with facilitating inter- and transdisciplinarity within their portfolios – i.e. as part of learning and teaching; research, innovation, and internationalisation; engagement; and institutional support arrangements.
- 4) Set up an advisory committee composed of successful inter- and transdisciplinary researchers to identify institutional barriers and advise on strategies to foster inter- and transdisciplinarity.

- 5) Identify priority areas for inter- and transdisciplinary research, educational programmes, and partnerships based on established and emerging institutional strengths.
- 6) Encourage and facilitate inter- and transdisciplinary interactions based on existing institutional strengths by:
 - a. Supporting joint collaborative activities such as workshops, conferences, or events with a broad reach in the academic community and beyond.
 - b. Providing seed grants for inter- and transdisciplinary research collaboration.
 - c. Establishing platforms to support researchers with a common interest with funding in priority areas. As incentives, these mechanisms should require competitive applications from the academic community submitted to a panel of experienced inter- and transdisciplinary researchers for peer review and approval.

5.2 Organisational design and governance arrangements

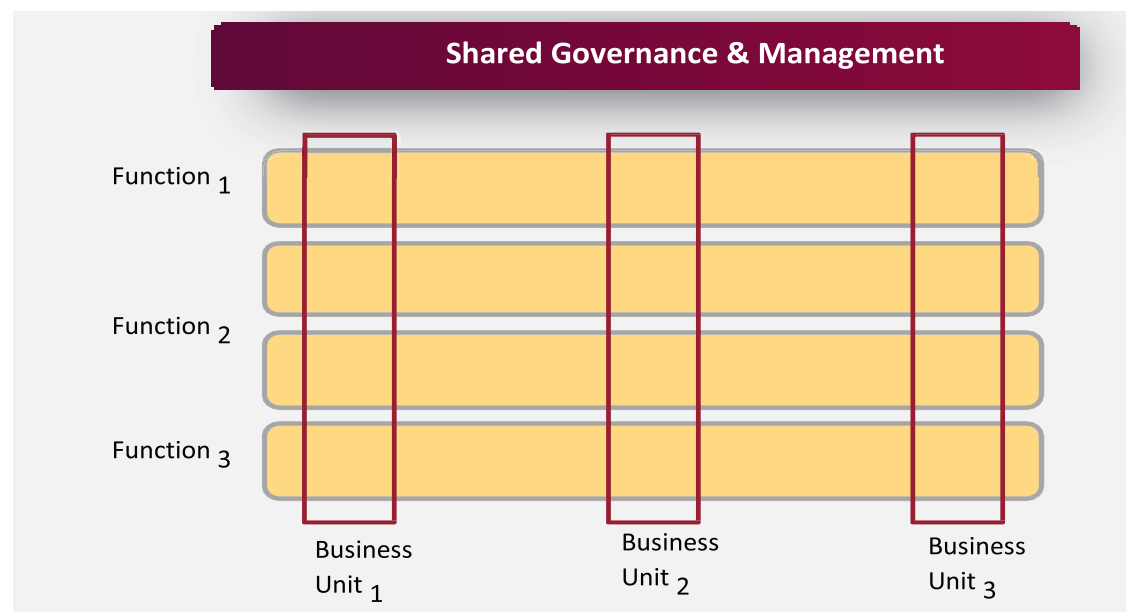
Organisational design and governance arrangements are important prerequisites in creating an enabling environment that fosters inter- and transdisciplinarity. In this regard, it is recommended as follows:

- 1) Ideally, transdisciplinary entities and projects with a common purpose and desired outcomes should be co-located at an independent physical location with an intellectual direction distinctive from traditional university departments. In cases where physical co-location is not possible, members of transdisciplinary research teams should be given the necessary training to use online collaboration platforms and their frequent face-to-face interaction should be encouraged, at least during the early phases of the project.
- 2) Build a flexible organisational environment by creating structures with an inter- and transdisciplinary mandate such as centres, institutes, joint laboratories, or scientific ateliers. The University could establish an affiliation system based on a matrix approach where researchers formally participate in these inter- and transdisciplinary structures while retaining their departmental and disciplinary affiliation. While inter- and transdisciplinary entities should be established as long-standing organisational arrangements, affiliated researchers should be appointed for flexible, intermittent short-term periods dictated by the needs of projects rather than administrative mandates. In this way, researchers are primarily affiliated with a disciplinary community but also participate in inter- and transdisciplinary projects for a specified duration.
- 3) Clear and well-articulated organising principles—problems, products, or projects— should be the basis for organising researchers based on their technical, methodological, or topical contributions.
- 4) Governance arrangements should allow for the co-creation of knowledge by scientists from different disciplinary backgrounds, with inputs from external societal stakeholders who are interested in and can positively influence the research outcomes. This can be a representative multi-stakeholder advisory board or steering committee, comprising internal and external stakeholders, responsible for the strategic direction of transdisciplinary entities.
- 5) Strategic and organisational flexibility will ensure that inter- or transdisciplinary groups can adapt to anticipated and unforeseen change. The variety of integrating networks and partnerships is not static but evolves through different types and scales of connectivity. This can be stimulated by

purposeful formal and informal opportunities for conversation and information exchange from one network or sub-group to another both within and external to the university.

- 6) Management and administrative staff should provide visionary and adaptive leadership, effective project coordination, and integrated support to inter- or transdisciplinary project teams. Team science involves a wide variety of actors, which requires higher levels of organised interactions. A shared services model can facilitate the convergence of project management and administrative support (see Figure 3 below). The following support functions may be housed in a cross-functional shared services centre: academic administration; stakeholder engagement, event management; marketing; catering; finance and procurement; human resources; information technology; estates and facilities management; and security. A shared services model must be performance-driven, client-responsive, and accountable for delivering integrated support services more efficiently than the status quo.

Figure 3: Multi-functional shared services centre model



5.3 Human resource arrangements

To maximise the potential for high achievement, researchers need to work in an environment, which stimulates and supports their creativity, curiosity, and passion for inter- and transdisciplinary connections and discovery. To achieve this, the university needs to devote attention to the following human resources arrangements:

- 1) Recruitment and selection criteria and practices should be customised to attract talented inter- and transdisciplinary researchers.
- 2) Early career researchers with the potential to participate in and lead inter- and transdisciplinary should be identified and supported through focused career development and mentoring.
- 3) Inter- and transdisciplinary research centres must be populated with scholars who can serve as “stars” and who can be “connectors.”

- 4) Universities need to reconsider the priorities and practices of postgraduate education and training to prepare promising scholars for engaging in inter- and transdisciplinarity. To this end, postgraduate education must not only educate future scholars to be experts in the methods, techniques, and theories of their chosen disciplines, but to inculcate the problem-solving and lateral thinking skills that enable learning, unlearning, and relearning across disciplines (Rhoten, 2004: 11).
- 5) Clear terms of reference and role allocation are important for researchers participating in transdisciplinary projects to reduce the risk associated with double administrative, teaching, and research loads.
- 6) Project team members must be allocated roles and functions early in the process to ensure they clearly understand how they can contribute to the project from academic, administrative, team facilitation, and stakeholder engagement perspectives.
- 7) Academic promotion and performance evaluation criteria should be revisited and broadened to ensure that inter- and transdisciplinary engagement is appropriately recognised and rewarded. This should include developing and disseminating explicit guidelines and criteria for assessing excellence in inter- and transdisciplinary research, teaching, curriculum development, and engagement.

5.4 Institutional culture arrangements

The sustainability of inter- and transdisciplinarity as a mode of knowledge production largely depends on the extent to which the university's institutional culture creates an enabling and supportive environment for this to flourish. To this end, focused organisational development interventions could embrace the following possibilities:

- 1) Broadly showcase successful inter- and transdisciplinary projects to internal and external audiences to cultivate an appreciation of the value and impact of such endeavours.
- 2) Organise public debates and events on relevant topics with the participation of scholars from different disciplines and other relevant societal actors to position the university as a knowledge institution engaged in addressing complex social challenges through inter- and transdisciplinary teaching, research, and engagement.
- 3) Recognise and value the contribution of academic schools and departments to facilitating and embedding inter- and transdisciplinarity in educational, research, and engagement activities. Schools and departments are expected to contribute substantial resources and staff to inter- and transdisciplinary collaborative endeavours, but these contributions are poorly accounted for by academic statistical systems that usually prohibit attributing students and research outputs to more than one structure. This results in unhealthy competition over resources between inter- and transdisciplinary entities and academic departments, which is counter-productive to creating a culture of collaboration.
- 4) Organise capacity development opportunities to facilitate inter- and transdisciplinary research and thinking.
- 5) Evaluate inter- and transdisciplinary projects and structures through cyclical review mechanisms and broadly share good practices.

- 6) Monitor the contributions of scholars to inter- and transdisciplinary scientific journals and publications.
- 7) Explore how information and communication technologies can facilitate inter- and transdisciplinary collaboration.

5.5 Funding and resource allocation arrangements

There is a tension between the need to support complementary disciplinary and inter- or transdisciplinary initiatives. Enhancing financial support for inter- and transdisciplinary teaching, research, and engagement should devote attention to the following:

- 1) Secure an earmarked institutional budget to support inter- and transdisciplinary education and research within the university with transparent allocation rules and criteria.
- 2) Identify and pursue funding opportunities requiring collaboration with external stakeholders, such as government, industry, and civil society.
- 3) Provide proposal writing and other relevant support and training opportunities to researchers to mobilise external funding for inter- and transdisciplinary research.
- 4) Allocate sufficient time to implement inter- and transdisciplinary research projects before evaluating and reviewing their performance. Transdisciplinary projects can produce high social and academic impact when undertaken properly and should be assessed on this basis (Gaziulusoy, 2017: 63).
- 5) Incorporate “buffer budgets” into transdisciplinary project proposals to make provision for unforeseen expenses that arise from the emergent challenges and complexities associated with integrative research. Buffer budgets would include an amount of funding indicated in project proposals, which are not allocated to any specific line item and can be used when justified new, unanticipated expenses occur during the project (Gaziulusoy, 2017: 62).
- 6) Allocate funding for the scholarship of inter- and transdisciplinary research and team science, which can improve practice.

6. Conclusion

In a highly competitive global knowledge society, universities are expected to generate pioneering and cutting-edge knowledge and innovation that contributes to addressing intractable societal and planetary sustainability challenges that extend beyond the scope of any single discipline. A key challenge is facilitating inter- and transdisciplinarity within academic institutions largely organised along conventional disciplinary lines. Addressing institutional barriers to embedding an enabling inter- and transdisciplinary scientific culture is the key to ensuring that inter- and transdisciplinarity become a force for excellence.

Strong disciplines are constitutive of impactful inter- and transdisciplinary research and the overarching strategic intention should be to sustain a virtuous circle between disciplinary and inter- and transdisciplinary knowledge creation. A systemic, yet flexible, approach is needed to harness the transformative potential of inter- and transdisciplinary education and research within a diverse and differentiated higher education landscape.

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