Chapter 2

Disciplines, Perspectives and Conversations

Gerard Mullally, Edmond Byrne and Colin Sage

Transdisciplinarity as a concept attracts a range of interpretations. Julie Thompson Klein, who has contributed clarity, context and classification to the concept – particularly in relation to other modes of knowledge production – is nonetheless short on comfort for the ontologically insecure and the epistemologically doubtful when she states that 'there is no universal theory, methodology, or definition of transdisciplinarity' (Klein, 2013, p.189). Where, then, does this leave us as we embark upon an exercise in 'transdisciplinary conversations'? A sociologist can at least look to the genesis narrative that she (and others) provide and which suggests some concordance with disciplinary canons that point to heterodoxy rather than heresy. To some extent, Nicolescu's (2010) ironic use of the phrase 'war of definition' in his discussion of the 'methodology of transdisciplinarity' at least allows the space, in the words of Beck, for the struggle for definition. Although, a less confrontational idea like Pohl's (2010) notion of a 'concept in flux' is probably more forgiving. Pohl (2010, p.81) suggests that rather than 'a unifying definition' a 'structured plurality of definitions' is a more likely outcome. Thus, as we can see from the outset, there are no singular paths through the tricky terrain of transdisciplinarity.

For a geographer cognizant that there is no single and unifying disciplinary perspective, it is possible to identify strands that have entangled different specialisms both within and beyond the discipline and that offer new engagements. Stock and Burton suggest that political ecology is a good example of a transdisciplinary sub-discipline that 'emerged from the transcendence of a number of disciplines—and has existed under the umbrella of a larger disciplinary body (Geography) since the 1970s though others associate it with interdisciplinary work' (Stock and Burton, 2011, p 1099). Also in a geographical vein the debate on transdisciplinarity is replete with topological and geo-political metaphors. Krishnan (2009, p.12) instances 'borders', 'boundaries', 'territories', 'kingdoms', 'fiefdoms', 'silos', 'empire building', 'federalism', 'migration' as metaphors for geographic territory in disciplinary parlance. He stresses, however, that 'there are lots of overlapping jurisdictions and constantly shifting and expanding knowledge formations. This makes the metaphor of "knowledge territories", which implies some stable or identifiable topography and some sort of zero-sum game over its distribution, sometimes quite misleading'.

For a scientist or engineer, although fictional physicist Sheldon Cooper from the *Big Bang Theory* would recoil in horror at their conflation, there is some solace to be found in the sociology, philosophy and history of science as well as a growing corpus of publications by key actors from various branches of science (the so called STEM disciplines) exploring and advocating transdisciplinarity (see Byrne, Chapter 3). While Cooper might well approve of Nicolescu's observation that physics is the only truly axiomatic discipline, he would nevertheless fail to find purchase for his prejudices regarding engineers as the under-labourers of science. For it is engineers, faced with a real world that is overwhelmingly and irreducibly complex in both its social and natural manifestations (which in virtually all cases are relevant, even to the engineer), that typically may seek resolution through adopting the types of contingent and pragmatic approaches that are appropriate in the wake of inherent uncertainty and the possibility of emergent knowledge that an open transdisciplinarity can facilitate (Byrne and Mullally, 2014).

Being Disciplined

Disciplines are defined as institutions, i.e. conventions, norms or formally sanctioned rules that coordinate human action (Castán Broto, Gislason and Ehlers, 2009, p.922). The early universities such as Salerno, Bologna, Oxford and Cambridge, started with Faculties of Medicine, Philosophy, Theology and Law (Max-Neef, 2005, p 6). Disciplines provide scientists with frames of reference, methodological approaches, topics of study, theoretical canons, and technologies (Stock and Burton, 2011, pp.1090-1091). Researchers are thus 'rooted' in a disciplinary epistemology necessary for increasing knowledge (in sociology, law, psychology, history, geography, physics, biology, mathematics, etc.) while also connecting with other disciplinary 'languages'. In this regard we can observe how researchers follow certain academic trajectories within 'disciplined' career paths but, at the same time, they also tend to hybridize, evolve and develop through contact with other disciplines (Darbellay, 2015, p.164).

The relationship to knowledge has deep roots in the ancient Western world and to some extent continues to exercise an influence over approaches to transdisciplinarity. The Platonic emphasis on the 'unity of knowledge' contrasts with Aristotle's divisions into theoretical and practical knowledge (Krishnan, 2009, p.13). Aristotle's forms of knowledge namely 'science (*episteme*), life-world action (*praxis*), production (*poêsis*), and prudence (*phronêsis*)' according to Hirsh Hadorn, et al. (2008, p.31), have become transformed in the contemporary world into the goals of transdisciplinarity.

Max-Neef (2005, p.6) points out that the association between disciplines, departments and institutes is a relatively modern phenomenon consolidating at the end of the 19th century. He notes that professors and *disciples* develop and enhance disciplinary loyalties up to the point of frequently feeling that theirs is the most important of the entire University. Darbellay (2015, p.169) evokes a similar imagery exploring the etymology of disciplinarity:

> The pupil or disciple (*discipulus* in Latin) is one who submits to a master, is bound by obedience and allegiance, and accepts the need for the lash of the 'discipline' (*disciplina* in Latin), i.e. the whip comprising thin cords or chains used as an instrument of penitence, mortification or coercive self-discipline.

Drawing on Foucault, Darbellay recognises that although disciplines control the production of scientific discourse and are 'defined by groups of objects, methods, their corpus of propositions considered to be true, the interplay of rules and definitions, of techniques and tools' (2015, p.170), it is simultaneously a fluid system which evolves through contact with other disciplines. In the late twentieth century with the re-contextualisation of disciplines, a weakening of boundaries contributed to changes in canons, codes and categories of knowledge production processes (Castán Broto, Gislason and Ehlers, 2009, p.923). O'Reilly (2009, p221) also drawing on etymology suggests that 'the word discipline has several connotations: a branch of knowledge, or a subject (noun: a discipline); the trait of being well-behaved, or to adhere to moral codes (adjective: to be disciplined); and even the act of punishing (verb: to discipline)'.

Wallerstein (2004, p.22-23) assigns three contemporary meanings to the usage of the word discipline in universities as: 'intellectual constructs', 'organizational containers' and 'cultural communities'. These correspond loosely to what Krishnan (2009) calls philosophical, sociological and anthropological understandings of disciplines. The first describes an intellectual circumscription of knowledge, a set of theories and methods designed to discuss a delimited range of phenomena of the real world, or epistemologies focused on unity and plurality. Disciplines are also understood as 'organizational' containers in the sense identified

by Max-Neef (2005), as faculties or departments. Wallerstein (2004) points out that from the middle of the nineteenth century there was considerable but not total convergence in the structuring of universities world-wide, and that departments had power and resources to try to shape and define what they contain. In Krishnan's characterisation, this is understood as professionalization and a division of labour. In the third meaning, disciplines are also 'cultural communities' in that intellectual training or socialisation within disciplines helps to shape preferences, belonging and emotional attachment which, for Krishnan, resemble the organisation of culture and tribes.

Wallerstein (2004) suggests that the presumed correlation between these different phenomena is less than perfect and can be subject to divergence over time. Indeed after the 1960s, the blurring of boundaries between intellectual distinctions has accelerated, while organisational containers have resisted redefinition and in this tension 'cultural communities' felt the impact of divergence. For Wallerstein (2004, p.25), this represents a bifurcation in our existing systems of knowledge, wherein Yeats' evocative (post Great War) phrase, 'the centre cannot hold; Mere anarchy is loosed upon the world' (Yeats, 1920), represents a sentiment which may provide a commentary on the revealed inherent uncertainty which accompanied the twentieth century exposure of modern reductionism as being wholly incapable of describing the totality of reality (see Byrne, chapter 3).

Bernstein (2014, p.248) notes that there is still considerable psychic investment in identifying with disciplines. Drawing on the idea of 'disciplinarian thinking', which encompasses both the etymological and phenomenological roots/routes of disciplines discussed, Bernstein suggests that disciplinary discourse 'can become "walled-off" from connections and feedbacks from outside, leading to territorialism, proprietary claims and notions of impropriety' (2014, p.248). In a more complex epistemology, however, Human and Cilliers (2013, p.29) point out that 'differentiation nevertheless remains problematic since it is constantly challenged. The nature of the boundary, of what is considered internal or external, is perpetually transformed by the threat of 'the outside' since the 'threat' simultaneously structures the 'inside' (cf. Wellbery, 2009; Webb, 2006).

Shrivastava and Ivanaj (2012, p.116) suggest that: 'our disciplinary understanding is highly fragmented, and organizationally filtered by political and social interests. We know more and more about less and less, and in a partial disconnected way'. Max-Neef (2005) makes a similar observation noting that we have reached a point in our evolution as human beings, wherein 'we know very much, but understand very little' (p.14). He goes on to observe (emphasis in the original): 'The *knowing* has grown exponentially, but only now do we begin to suspect that this may not be sufficient, not for quantitative reasons, but for qualitative reasons' (p.15). For Max-Neef (p.15) 'the other side of the coin to knowledge is that of *understanding*'. Perhaps Shakespeare's Hamlet put it best: 'There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy'.

This pursuit of knowledge has given rise to growing specialization and fragmentation, particularly throughout the 20th Century. As Shrivastava and Ivanaj (2012, p.116) account:

> In the year 1250 there were only 7 distinct disciplines (In 1251 the University of Paris had 4 Departments). By 1950 there were 54 disciplines. In 1975 the JACS4 - Higher Education Statistics Agency of UK recorded 1845 disciplines. In 2010 National Register of Scientific and Technical Personnel, National Science Foundation (NSF) archives, USA) listed 8000 scientific disciplines.

The multiplication of a huge variety of disciplines and sub-disciplines has been backed by the proliferation of 'specialized journals and reviews and also by the institutional structure set up for the accreditation, evaluation, and funding of research projects and courses' (Bursztyn, 2008, pp.2-3). Rau and Fahy (2013, p.14) reflecting on the role of funding structures, institutional conditions, quality indicators and output metrics that could inhibit or facilitate weaker and stronger forms of transdisciplinarity, suggest that to some extent, open source publishing and innovation in interdisciplinary/transdisciplinary journal titles have recognised the gatekeeping function of many academic periodicals and that these new spaces are borne of frustration with the *status quo*.

This is leading to a growing reflection and uncertainty about the nature of the disciplinary organization of the university. Within the social sciences this has been reflected in the demand to 'open the social sciences' (Gulbenkian Commission, 1996). More generally, in Europe, the Bologna process aimed to create a higher education area on a continental scale 'to simplify and unify the University systems … based on mobility, employability and interdisciplinarity' (Bursztyn, 2008, p.5). Hershock (2010, p.35) makes an important distinction between quantitative *variety* and qualitative *diversity:*

> Variety is a quantitative index of simple multiplicity that connotes things simply being-different. A function of either simple or complicated co-existence, variety is readily seen at a glance. Diversity is a qualitative index of self-sustaining and difference-enriching patterns of mutual contribution to shared welfare. A function of complex, coordination-enriching interdependence, diversification entails opening new modalities of interaction. As such, diversity is a relational achievement that emerges and becomes evident, if at all, only over time.

The contemporary university is characterized by a struggle between two agonistic competing trends (see also Byrne, Chapters 3 and 4): 'The hegemonic trend builds upon the industrial society model of fragmentation, prescription, management, control, and accountability, while the marginal trend is based on integration, self-determination, agency, learning, and reflexivity' (Peters and Wals, 2013, p.86). In such a context, Frodeman (2014, p.207) questions the overproduction of knowledge surmising that 'the age of disciplinary knowledge may be ending, but the shape of a transdisciplinary age is yet unknown'. While we suggest that rumours of the demise of disciplinarity may be greatly exaggerated, the question he begs is relevant. Is it possible, he asks, 'to map out a theoretical space between being lost in specialized expertise and mere learned generalities, and to fashion an account of how much knowledge is enough?' Klein (2004, p.2) has identified several moments in a putative shift:

> The metaphor of unity, with its accompanying values of universality and certainty, has been replaced by metaphors of plurality [and] relationality in a complex world. Images of boundary crossing and cross-fertilization are superseding images of disciplinary depth and compartmentalization. Isolated modes of work are being supplanted by affiliations, coalitions, and alliances. And, older values of control, mastery, and expertise are being reformulated as dialogue, interaction, and negotiation.

Nicolescu (2010, p.21) insists on the unity of knowledge 'unified (in the sense of the unification of different transdisciplinary boundaries), and diverse: unity in diversity and diversity through unity is inherent to transdisciplinarity'. Morin's concept of 'unitas multiplex', one which 'escapes abstract unity whether high (holism) or low (reductionism)' (Morin, 2008, p.6) strikes a similar chord, going 'beyond classical either/or alternatives':

> reductionism has always provoked an opposing holistic current founded on the pre-eminence of the concept of globality or totality. But the totality is never anything more than a plastic bag enveloping whatever it found any way it could, and enveloping too well: the more the totality becomes full, the emptier it becomes. On the contrary, what we want to draw out, beyond reductionism and holism, is the idea of complex unity, that links analytical-reductionist thinking and global thinking, in a dialogic … This means that if reduction … will remain an essential character of the scientific mind, it is no longer the only, nor, particularly, the last, word (Morin, 2008, p.33).

For Klein (2014a, p.69), the emphasis on unity has a long and contested heritage in Western thought stretching from ancient Greece, to the medieval Christian *summa*, the Enlightenment ambition of universal reason and *Encyclopédie* project[1]. At a glance this raises the spectre of what Pohl (cited in Stock and Burton, 2011, p.1098) has suggested haunts some versions of transdisciplinarity as a 'megalomaniac' endeavour. This charge is not unique to transdisciplinarity; Katunarić (2009, p.204) for example describes some aspects of sociology (particularly Comte's vision of sociology as the 'Queen of Sciences') as 'theoretical megalomania', as indeed does Joas (2004, p.303). Within much of the literature on transdisciplinarity, however, the vision is relatively limited and contained, understood as a research principle (Webb, 2006, p 92): 'It does not necessarily imply a transcendent or trans-scientific philosophical *holism* (that modern equivalent of the philosopher's stone - a Grand Unifying Theory)', as articulated by Morin's top down holism (above). However, Klein highlights the nuance of Nicolescu's position:

> The expanding number of disciplinary specialties coupled with formation of new interdisciplinary communities of practice led to greater heterogeneity and hybridity of knowledge. As a result, the logic of 'unity' moved toward the logic of 'unifying' approaches, relationality and coherence became prime values, and interplay, intersection, interdependence became defining characteristics of knowledge production (Klein, 2013, p.192).

Klein characterises Nicolescu's vision as a commitment to 'long-term dialogue based on the three pillars of complexity, multiple levels of reality, and logic of included middle' (2013, pp.192-193). She points out that it is not a simple transfer of a model from one branch of knowledge to another, nor a complete theory 'for moving from one level of reality to another', or even 'a new super discipline of science'. Rather, it is 'a "moral project" that is simultaneously transdisciplinary, transnational and transcultural'. Ramadier (2004, p.427) suggests that the logic of the included middle represents 'something above binary logic, thanks to which a third term can *emerge*… not a synthesis of the first two, as it would be in Hegelian logic, but a *complementary* element included in the relationship between the first two elements' (emphases added). Du Plessis and colleagues also tease out from Nicolescu this area of

[1] Klein goes on to say that Raymond Miller defines transdisciplinarity as 'articulated conceptual frameworks' that transcend the narrow scope of disciplinary worldviews. Leading examples have included not only two approaches that loomed large in 1970 – general systems and structuralism – but also Marxism, phenomenology, policy sciences, and sociobiology. Holistic in intent, they proposed to reorganize the structure of knowledge by metaphorically encompassing parts of material fields that disciplines handle separately (Klein, 2014a, p.69-70).

discontinuity, this 'middle ground', which is a space 'filled with possibilities of the 'unknown'' (Du Plessis, Sehume and Martin, 2014, p 54).

Dockendorff (2011) also acknowledges that 'transdisciplinarity concerns the dynamic engendered by several levels of reality at once', but cautions that 'although we recognize the radically distinct character of transdisciplinarity in relation to disciplinarity, multidisciplinarity and interdisciplinarity, it would be extremely difficult to absolutize this distinction'. She notes, following Nicolescu, that the confusion of terms can be 'harmful to the extent that it functions to hide the different goals of these three new approaches', but argues (presumably against Nicolescu) that the confusion arises 'because not even those who are interested can accept the novelty of [transdisciplinarity] proposals in its entirety, much less those of strict scientific thought'. Webb (2006, p.97) comes to a similar realization, in that 'the assumption that transdisciplinarity inevitably leads to a questioning of "the intrinsic possibility of certainties" could be seen as a step too far, even by some proponents of transdisciplinarity'. However, Giri (2012, p.321) suggests that this may be precisely where the desire or passion for transdisciplinarity might emanate since: 'traditional disciplinary categories do not reflect the profusion, confusion and richness that working scholars use to think of themselves'.

Distinctions and Translations: Intra-, Inter-,Trans-Disciplinarity

Cooper (2013, p.78) suggests that **'**one response to, and symptom of, all this heterogeneity is to distinguish between and construct typologies of the different forms that it can take'. Interestingly, the very act of classification is, of itself, a means of *disciplining* difference and drawing *distinctions* which, adapting Bourdieu to our purpose, means that 'social subjects, classified by their classifications, distinguish themselves by the distinctions they make, between the beautiful and the ugly, the distinguished and the vulgar, in which their position in the objective classifications is expressed or betrayed' (Bordieu, 1984, p.6). Notwithstanding these cautionary notes, it remains a salutary exercise in drawing distinctions between the disciplinary prefix.

Intradisciplinarity

Du Plessis, Sehume and Martin acknowledge that 'academia is ruled by repeated reference to a unity of disciplinary action – action that requires academics to be directed towards a purpose filled strategic direction' (Du Plessis, Sehume and Martin, 2014, p.29) Yet, Darbellay suggests that 'when subject to closer scrutiny, every discipline presents a configuration of currents and schools of thought that traverse it from one end to the other as though through fragmentation and internal diversification' (Darbellay, 2015, p 170). For him, this means that we need to consider that 'disciplinary identities are not as solidly rooted as the academic organization would sometimes like us to believe'. To be fair, many of the authors drawn upon here are explicit on this point. For some this can be seen as a kind of internal differentiation within disciplines. Fuchsman rejects the notion of disciplinary unity as 'triply false: minimizing or denying differences that exist across the plurality of specialties grouped loosely under a single disciplinary label, undervaluing connections across specialties of separate disciplines, and discouraging the frequency and impact of cross-disciplinary influences' (2009, p.74). He goes on to identify five dynamic patterns within disciplines: '(1) agreement about objects, ideas and methods which provides for a disciplinary foundation, (2) contending discourses which can cause researchers to pursue parallel lines, (3) the competition which can result in synthesis between once opposing views, (4) ideological splits which can inhibit disciplinary agreement,

and (5) fragmentation between sub-fields which results in a minimum of interaction between disciplinary specialties' (Fuchsman, 2009, p.75).

Wellbery (2009) adopts an evolutionary view of disciplines as social sub-systems from the point of view of complexity. In doing so he rejects accounts of disciplines as either the result of functional differentiation or rule based understanding of disciplines. He sees disciplines (and by extension sub-disciplines) as emerging from the proliferation of knowledge leading to 'formation of sub-units capable of maintaining a balance between redundancy and variety, that is, between the production of plausible coherencies and the admission of more variegated detail' (Wellbery, 2009 p.985). In his account the reduction of complexity is achieved by 'allocating a burgeoning topic to a specialized sub-field'. The impetus towards interdisciplinarity stems from disciplinary differentiation creating 'a background noise of rumours about what is being said, thought, and written *over there* on the other side of the disciplinary boundary that circumscribes individual competence' (p.986). Wellbery counters the notion of disciplines as control and constraint with the idea that they are also plastic 'that is to say susceptible to evolution, capable of learning' (p.989). Disciplines are conceived of as subsystems of the social system of science, that consist of communicative operations that are recursively generated, that hook up with and refer to and generate successor communications (p.990). This segmental differentiation consolidates new system-environment distinctions generating the problem of interdisciplinarity (on which more below) and which 'is a matter of inter-systemic communications'. For Wellbery, three types of interface make this communication possible 'despite systemic closure (or "autonomy"): bits of borrowed vocabulary (occasional interdisciplinarity), hybrid objects (problem oriented interdisciplinarity), and theories (transdisciplinarity)'. Disciplines, he concludes, 'do not reside within boundaries; they are the ongoing re-inscription of the distinction between what is pertinent to them and what is not' (p.994). Webb (2006, p.105), however, suggests that 'even if closure is inevitable, transdisciplinarity provides an opportunity to test the boundaries; to find openings that are themselves immanent in the creative tensions that exist between the disciplinary flows and networks of information, and in the interstices and "undecidables" that emerge within a disciplinary knowledge'.

Hukkinen and Huutoniemi (2014, p.179) have a similar understanding of disciplines insofar as: 'disciplines produce knowledge in the sense that they create and maintain coherence against entropy and dissolution. Coherence is the outcome of connectivity and ties within a network, and then of higher internal rather than external connectivity and density'. Networks learn, but 'the accumulation of knowledge is not an increasing proximity to the real world, but an increasing self-similarity … a network, such as a discipline, is always simpler or more coherent than the world at large'. Disciplines as technologies of knowing and seeing can also produce 'patterns of blindness, because a way of seeing something is always, at the same time, a way of not seeing something else' (pp.179-80). The reduction necessarily inherent in disciplinarity thus precipitates the unintended side effect amounting to visual impairment, particularly when dealing with the irreducible complexity inherent in all non-trivial natural, social and/or techno-economic systems of any significance. Morin (2008, p.5) elaborates on this point when he suggests:

> Complexity presents itself with the disturbing traits of a mess, of the inextricable, of disorder, of ambiguity, of uncertainty. Hence the necessity for knowledge to put phenomena in order by repressing disorder, by pushing aside the uncertain. … But such operations, necessary for intelligibility, risk leading us to blindness if they eliminate

> other characteristics of the complexus. And in fact, as I have argued, they have made us blind.

Morin further elaborates:

> We are blind to the problem of complexity. …This blindness is part of our barbarism. It makes us realize that in the world of ideas, we are still in an age of barbarism. We are still in the prehistory of the human mind. Only complex thought will allow us to civilize knowledge (Morin, 2008, p.6).

By extension and in the context of extending beyond narrow disciplinary confines in order to develop (an appropriate) transcendent vision, Hukkinen and Huutoniemi (2014, p.179) thus argue that rather than viewing 'the embeddedness of knowledge and its context of production' as distorting or undermining science, the 'embedded process of cognition' (which we read as immanence) could fruitfully be linked to the search for solutions to sustainability problems when understood from a complexity informed perspective.

Multidisciplinarity

Multidisciplinarity was well established by the 1980s, according to Bursztyn (2008, p.5), 'although not aiming to replace the disciplinary structure materialized in departments, subjects such as planning studies, development studies, urban and regional studies etc. became focused in centres'. Mobjörk (2010, p.867) helpfully describes research in this context as an *anthology* model: collaboration between researchers from different disciplines investigating a specific problem from their respective angle using each discipline's conventional methods. It can thus be understood as 'a division of labour' [functional specialisation], with 'specialists working together, maintaining their disciplinary approaches and perspectives'.

With multidisciplinarity, the degree of integration is addressed in a subsequent synthesis phase and does not affect the approaches shaping the research. For Darbellay (2015, p.165) it involves 'a given object of study or a theoretical and/or practical problem that requires resolution [and] is approached from two or more unconnected disciplinary viewpoints, in succession and in isolation without any real interaction between them'. It reflects, for him, 'the traditional institutional juxtaposition of a number of communities of specialists, organized in the same number of relatively autonomous faculties, departments and laboratories'. In this context, 'the actual concept of the discipline mainly provides the basis – like a fixed threshold – from which an inter[disciplinary] and transdisciplinary approach is constructed, however it is rarely questioned in itself and never radically challenged' (Darbellay, 2015, p.170). Wickson, Carew and Russell (2006, p.1049) suggest that while multidisciplinarity involves 'the juxtaposition of theoretical models belonging to different disciplines', it is characterised by the unintegrated application of more than one disciplinary methodology. Multidisciplinarity, according to Repko (2012, p.16), is a relationship of proximity. For Stock and Burton (2011), 'multidisciplinarity features several academic disciplines in a thematically based investigation with multiple goals – essentially, studies "co-exist in a context"', while 'research approaches are disciplinary, the different perspectives on the issue can be gathered into one report for assessment' (2011, p.1095). Bursztyn (2008, p.5) suggests that 'studies' tend to have a problem-oriented identity and a dependency on various disciplinary fields. By not claiming the status of a specific science, studies manage to gain legitimacy and acceptance. Repko (2012, pp.18-19) recounts the fable of building an elephant house to illustrate the ways in which disciplinary experts orient to complex problems from the monistic disciplinary perspective of their speciality, failing to take account of the perspectives of relevant disciplines, professions

or interested parties. Although, too long to reproduce in full the opening lines can give a sense of the lesson intended:

> Once upon a time a planning group was formed to design a house for an elephant. On the committee were an architect, an interior designer, an engineer, a sociologist, and a psychologist. The elephant was highly educated too . . . but he was not on the committee.

In summary, Nicolescu (2010, p.22) argues that 'the multidisciplinary approach overflows disciplinary boundaries while its goal remains limited to the framework of disciplinary research'. From a social science perspective Horlick-Jones and Sime (2004, p.446) caution that a multidisciplinary analysis that assumes all social science knowledge is epistemologically homogeneous can result in a kind of selective inclusion that seeks to secure legitimacy over learning. Darbellay (2015, p.170) also notes the tendency for any heterodox posture to stabilize as a new orthodoxy as is the case with multi-disciplinary fields performing a new 'disciplinarization' of knowledge in the form of emerging studies (e.g. gender, post-colonial, environmental).

Interdisciplinarity

Klein (2014b, p.2) notes that while WWII represented a watershed in interdisciplinary research marked by large scale collaborative projects to solve military problems that led to the etymology of interdisciplinarity, she suggests that the term was shorthand as far back as the early 1920s for research that crossed divisions of the Social Science Research Council and which focused on social problems such as poverty, crime and war. Castán Broto, Gislason and Ehlers (2009, p.923) argue that by the 1980s Clifford Geertz had 'brought interdisciplinarity into scientific discourse by stating the need for genre mixing in the social sciences and humanities'. In institutional terms the 1980s were also characterised by growing pressure for technology initiatives that blurred the boundaries - not only of disciplines - but also of the academy, government and industry (Klein, 2014b, p.2). Klein points to the development of offices of technology transfer, contract research and hybrid communities of industrial liaison programmes, joint ventures, and entrepreneurial firms as examples of institutional innovation from the period.

Interdisciplinarity is characterised by collaboration between researchers from different disciplines, but 'the research process is jointly established to develop a common methodological approach and a shared problem formulation' (Mobjörk, 2010, p.868). Interdisciplinarity, according to Fuchsman (2009, p.82) goes much further than juxtaposing different disciplinary viewpoints, it 'examines the fragmentations, interstices and contending discourses within and between disciplines in order to confront epistemological plurality and intellectual complexity'. For Darbellay (2015, p.165-166) interdisciplinarity 'involves a collaborative and integrative approach by disciplines to a common object, in the joint production of knowledge'. Collaboration and integration can, he argues, take place at a variety of levels of interaction. It can, for example, involve transferring or borrowing concepts or methods from other disciplinary fields and in this respect appears to resonate with Wellbery's idea of 'enrichment through contingent encounter' where 'terms and concepts rooted in one discipline are transported to another and generate unforeseen possibilities' as well as 'an element of misunderstanding or at least a penumbra of semantic indefiniteness' (Wellbery, 2009, p.988). The process can also involve hybridization or crossing mechanisms between disciplines or even the creation of new fields of research (Darbellay, 2015). The organization of knowledge along interdisciplinary lines is, he argues, 'based on the interaction between

several points of view, with the issues and problems treated falling 'between' (inter) existing disciplines, being recalcitrant to treatment by a single discipline' (Darbellay, 2015, pp.165-166).

Castán Broto, Gislason and Ehlers (2009, p.931) warn that once 'the requirements of interdisciplinarity are formalised, new institutions move from the margins to the centre and become, *de facto*, a new institutionalised hybrid discipline'. Thus the 'formalisation of interdisciplinary research may compromise its capacity to challenge current states of affairs and generate critical experimental spaces within which knowledge related institutions can be redefined'. Webb (2006, p 100) goes even further stating that interdisciplinarity is a paradoxical solution to the problem of disciplinarity assuming 'both the permeability of discipline boundaries and the "existence and relative resilience" of those same disciplines':

> This paradox seems to be resolved by interdisciplinarity creating a knowledge that is always transitional and transitory. Its fate is either to be rejected, in which case it is effectively lost to the system it seeks to influence or irritate, or it will be accepted and absorbed by its host, in which case it again loses its 'inter' character.

Others (Fitzgerald and Callard, 2015, p.15-16) seek to eschew the label of interdisciplinarity entirely:

> Our intimacy over a number of years with a number of these explicitly designated "interdisciplinary" spaces has strengthened our conviction that their governing ethic of epistemological seclusion (of the social sciences/humanities from the neurosciences, and vice versa) is a recalcitrant fantasy – one premised on a sanitized history of disciplinary domains, of the frequent intimacies that have enjoined them, and of their respective objects of study.

They suggest that we need to be attentive to 'the digressions and transgressions of smaller research units below the level of disciplines, in which knowledge has not yet become labelled and classified, and in which new forms of knowledge can take shape at any time' (p.17). Accordingly, Fitzgerald and Callard (2015, p.23) argue that:

> The pressing question, it seems to us, is how, as human scientists, we are to produce knowledge amid a growing realization that those boundaries are pasted across objects which are quite indifferent to a bureaucratic division between disciplines; and that scholars and researchers of all stripes invariably attend to, and live among, objects whose emergence, growth, development, action, and disappearance do not at all admit of neat cuts.

Robinson (2008, pp.71-72) approaches the issue of interdisciplinarity from the perspective of different temperaments, namely 'discipline-based interdisciplinarity' and 'issue-driven interdisciplinarity'. In the case of the former, the focus is on the interrelationship between disciplines, 'the intellectual puzzles and questions that lurk on the margins of established knowledge, and that offer the intriguing possibility of creating new understandings, drawing from established bodies of theoretical thought'. Robinson suggests that the approaches developed in this perspective are often proto-disciplinary in the sense that they map out the boundaries of new disciplines or sub-disciplines. The second type of temperament is more interested in the 'fundamental dilemmas or crises in society that do not seem to lend themselves to easy solution by traditional approaches'. This 'issue-driven interdisciplinarity' places 'a very strong focus on partnerships with the external world, partnerships which go beyond treating partners primarily as audiences, and instead involves these partners as co-producers of new

hybrid forms of knowledge'. Stock and Burton (2011, p.1097) make a similar distinction dividing interdisciplinarity into 'unidirectional' and 'goal oriented' varieties. In the case of the former, 'a single discipline may dominate and effectively control the integration of knowledge (e.g., adopting a modelling approach as a unifying framework)'. In the case of the latter, the interaction and development of the project is guided by the issue being studied, bringing us closer to the idea of transdisciplinarity.

For researchers positioned on the cusp of these challenges this involves reinventing the academy. Barry and Farrell (2013, p.122) propose that 'overcoming the substantial institutional and personal challenges that continue to face researchers … demands not only individual effort and creativity but also collective action and political commitment to institutional and cultural change within the academy'. The idea of 'issue driven interdisciplinarity' or 'goal oriented interdisciplinarity' often shades over into the debate on transdisciplinarity. For Jahn, Bergmann and Keil (2012), transdisciplinarity is an extension of interdisciplinary norms and forms of problem specific integration of knowledge and methods. Burzstyn (2008, p.16) attaches positive and negative attributes to the institutionalisation of interdisciplinarity. On the one hand, he characterises 'sustainability science', for example, as 'a reaction to the need to solve problems related to life support systems by integrating natural and social sciences … stepping into the academic world with an original institutional arrangement', aggregating rather than segregating. On the other hand, using the same language as Barry and Farrell he speaks of these spaces as an epistemological 'no man's land', or alternatively as (p.10) *La Cage aux Folles* 'a depository for confining problematic personalities'.

Transdisciplinarity

Jean Piaget is attributed as being the first to coin the term 'transdisciplinarity', when along with the likes of Erich Jantsch and André Lichnerowicz, they considered the term at a 1970 workshop on *'Interdisciplinarity – Teaching and Research Problems in Universities'* at Nice, France (Nicolescu, 2008, p.11). Piaget conceived of transdisciplinarity as that 'which will not be limited to recognize the interactions and/or reciprocities between the specialized researches, but which will locate these links inside a total system without stable boundaries between the disciplines' (Piaget, 1972, cited in Nicolescu, 2008, p.11). Jantsch meanwhile considered transdisciplinarity in terms of a hyperdiscipline, though he also envisaged 'the necessity of inventing an axiomatic approach for transdisciplinarity and also of introducing values in this field of knowledge' (Nicolescu, 2006b, p.2). Elements of these earlier conceptions (e.g. as a hyperdiscipline, implications of a closed ('total') knowledge system) were deemed unnecessarily restrictive and unsatisfactory to later proponents of the term *contra* the seminal twentieth century developments in the sciences of quantum physics and mathematical logic (by Heisenberg, Gödel and others). The implication of knowledge within a total (i.e. closed) system accordingly regarded the 'trans' as merely extending 'across' and 'between' disciplinary bounds, without truly going *'beyond'* them (Nicolescu, 2006a, p.142). Indeed, Lima de Freitas, Edgar Morin and Basarab Nicolescu framed a contemporary conception of transdisciplinarity through a '*Charter of Transdisciplinarity*', adopted by delegates at the first *World Congress of Transdisciplinarity* at Arrábida, Portugal in 1994 (de Freitas, Morin and Nicolescu, 1994; Nicolescu, 2008, p.254). This was inspired precisely by the advances and insights of Gödel and Heisenberg on the inherent axiomatic openness/incompleteness of knowledge and the necessary requirement of the Subject as an intrinsic part of Reality, as well as that of the agonistic Object (in addition to a necessary (third) *interaction* between them) in any ontological scheme (Nicolescu, 1998; 2006a, pp.143, 149-150; 2006b, pp.11-17; 2008, pp.8-10). While resolutely rejecting any claims that transdisciplinarity would constitute a new science of sciences, philosophy, religion or metaphysics (article 7), the charter boldly proclaimed a

radically open (i.e. 'acceptance of the unknown' (article 14)), pluralistic, contextual and global approach to the development of new and emergent knowledge, one which is capable of offering 'us a new vision of nature and reality' (article 3) (emphases added):

> The keystone of transdisciplinarity is the semantic and practical unification of the meanings that traverse and lay *beyond* different disciplines. It presupposes an open-minded rationality by re-examining the concepts of 'definition' and 'objectivity'. An excess of formalism, rigidity of definitions and a claim to total objectivity, entailing the exclusion of the subject, can only have a life-negating effect (article 4).
>
> The transdisciplinary vision is resolutely open insofar as it goes *beyond* the field of the exact sciences and demands their *dialogue* and their *reconciliation* with the humanities and the social sciences, as well as with art, literature, poetry and spiritual experience (article 5) (de Freitas, Morin and Nicolescu, 1994; Nicolescu, 2008, p.254).

While this approach is both grounded in and inspired by contemporary (post reductionist/ post-materialist) developments in mathematics and physics[2], it also requires approaches and applications which are at once 'contextual, concrete and global' (article 11). The range of areas which may benefit from such a transdisciplinary approach is infinite, including for example the realms of bioethics, consciousness, (addressing) cultural and religious differences, economic risk management, healthcare, higher education, mechatronics, networks of networks, spirituality, and sustainable enterprises (Nicolescu, 2006a; 2012), in addition to the diverse fields such as biotechnology (Haribabu, 2008), the arts (Johnston, 2008) and design studies (Nzi iyo Nsega, 2008). Place and space too are important in transdisciplinarity approaches (McGregor, 2012), a theme which befits the context of this publication. Such a transdisciplinary approach therefore provides a sound basis for facilitating a critical focus on the 'polycrisis' around global (un)sustainability and its underlying drivers (Morin, 1999).

Another 'strand' of transdisciplinarity, centred around a quite specific context, emerged in 1994 with the publication of '*The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*' by Michael Gibbons, Helga Nowotny and others (Gibbons, et al., 1994). This conception would still see transdisciplinarity (or 'transdisciplinary research' as it is sometimes called in this context (e.g. Hirsch Hadorn, et al., 2008)) as requiring a leap beyond disciplinary boundaries, but places greater emphasis on problem oriented research as it is applied to social and/or societal problems; that is, it is considered 'the mobilization of a range of theoretical perspectives and practical methodologies to solve problems' (Nowotny, Scott and Gibbons, 2003, p.180). Indeed, by this approach transdisciplinary research starts from tangible, real-world problems and embraces 'a new form of learning and problem solving involving cooperation among different parts of society and academia in order to meet complex challenges of society' (Häberli, et al., 2001, p.7). Transdisciplinarity is seen here as a means to employ what the authors call Mode 2 ('knowledge production') as opposed to classical Mode 1 ('research'), typically applied around the nexus of science, society and policy (Pohl, 2008). This approach has clear resonances with Funtowicz and Ravetz's conceptions of 'post normal' (as opposed to 'normal') science (Funtowicz and Ravetz, 1993), in which public and non-expert inputs are employed in problem framing and tackling, though there exist some historical and conceptual differences (Schiemann, 2011, pp.432-435). Nowotny, Scott and Gibbons (2003, p.179) thus describe Mode 2 as 'a new paradigm of knowledge production, which was socially distributed, application-oriented, trans-

[2] Mirroring the backgrounds and insights of some prominent pioneers and advocates such as Basarab Nicolescu (a nuclear physicist) and Erich Jantsch (an astrophysicist)

disciplinary, and subject to multiple accountabilities'. This represents an advance on what they call 'the old paradigm of scientific discovery ('Mode 1') – characterized by the hegemony of theoretical or experimental science; by an internally-driven taxonomy of disciplines; and by the autonomy of scientists and their host institutions, the universities' (Nowotny, Scott and Gibbons, 2003, p.179). Five distinctive characteristics can be attributed to 'Mode 2 knowledge production' (Gibbons, et al, 1994; Nowotny, Scott and Gibbons, 2003):

1. It is generated in *context;*

2. It is transdisciplinary i.e. it draws on a range of theoretical perspectives and practical methodologies in solving problems;

3. It draws from and across a wide diversity of knowledge sources;

4. It is highly reflexive, involving ongoing dialogic process/conversation; and

5. It is not easily measurable or subject to traditional reductionist forms of quality control.

This approach therefore seeks to go beyond reductionism in recognising inherent system complexity and messiness, thus readily finding practical and widespread application in socio-scientific issues in the realm of global (un)sustainability (Brandt, et al., 2013). Nevertheless proponents of the other 'strand' of transdisciplinarity would suggest that this approach only recognises a single level of reality, and thus while it can be helpful in offering 'a practical way of tackling problems in a more systemic way', it is 'far from sufficient' (Max-Neef, 2005) in the face of what Morin calls 'general complexity' (as opposed to 'restricted complexity') (Morin, 2007; Cilliers, 2007, 2008).

The body of literature associated with this strand of transdisciplinarity, which largely emanates from the German speaking world (Switzerland, Austria, Germany), is generally distinct from that of the former conception (which is more centred on the French, as well as other Latin languages). While the German speaking conception finds resonance and inspiration in science and technology studies (STS), science in society and the sociology of science (transdisciplinarity being 'firstly … related to the dialogue between science and society and to the implementation of the results to scientific research' (Hirsch Hadorn, Pohl and Scheringer, 2002)), the other conception is influenced by a methodology 'deeply informed by the new sciences of quantum physics, chaos theory, and living systems theory' (McGregor and Volckmann, 2011, p.6). The latter is thus more closely aligned with various emergent, or what might be called *integrative*, worldviews (Gidley, 2013; see also Byrne, Chapter 3). Coming from that (latter) perspective, Nicolescu would classify the 'German language' school as being purveyors of 'phenomenological transdisciplinarity' i.e. 'building models connecting the theoretical principles with the already observed experimental data, in order to predict future results', while he would conceive his own work as representing 'theoretical transdisciplinarity', one concerned with seeking a 'a general definition of transdisciplinarity and a well-defined methodology (which has to be distinguished from "methods": a single methodology corresponds to a great number of different methods)' (Nicolescu, 2008, p.12). He describes also a third facet; 'experimental transdisciplinarity', which 'concerns a large number of experimental data collected not only within the framework of knowledge production, but also in fields such as education, psychoanalysis, the treatment of pain in terminal diseases, drug addiction, art, literature, history of religions, and so forth' (p.13). He thus argues that conceptions of transdisciplinarity should go beyond seeking the (necessary, but incomplete) task of 'joint problem solving' that 'Mode 2 knowledge production' would envisage,

cautioning against framing/constraining transdisciplinarity such that it would be concerned with 'only society, as a uniform whole', thus neglecting 'above all the human being who is (or ought to be) in the centre of any civilized society' (p.12). In addition, Nicolescu is less than comfortable with a discourse around a transdisciplinarity which would envision the concept solely from an 'objective' 'scientific' basis, asking rhetorically: 'Why does the potential of transdisciplinarity have to be reduced to produce 'better science'? Why does transdisciplinarity have to be reduced to 'hard science'? To me, the Subject/Object interaction seems to be at the very core of transdisciplinarity, and not the Object alone'. (p.12). Nicolescu (2006a, p.145) thus expresses the fear that 'the huge potential of transdisciplinarity will never be realised if we do not accept the simultaneous and rigorous consideration of the three aspects of transdisciplinarity' (see below); moreover he suggests that the reduction of transdisciplinarity to only one of its aspects would be a dangerous path as it would risk manoeuvring transdisciplinarity into a temporary and transient fad (Nicolescu, 2008, p.13). On the contrary, simultaneous consideration of all three will allow for a 'unified' approach which can facilitate the coexistence of 'a plurality of transdisciplinary models' (p.13). This coheres with the view, expressed by Max-Neef (2005, p.15-16) that 'we will continue generating ever greater harms to Society and to Nature, because of our partial, fragmented and limited visions and assumptions' unless we manage to 'practice transdisciplinarity in a systematic manner, whether in its weak or strong version (depending on possibilities), and make efforts to perfect it as a world vision, until the weak is absorbed and consolidated in the strong'. The 'weak' and 'strong' versions identified here correspond with the 'Mode 2' and the 'included middle/levels of Reality' (see below) conceptions respectively.

The above discussion helps reveal the ontological fissures that exist between both conceptions of transdisciplinarity. Nicolescu (2006a, p.144) likens the conceptual difference to that between those who would envisage (disciplinary) boundaries as analogous to those between countries and the oceans, being constantly changing but nevertheless contiguous and continuous; and to those (like himself) who would see such boundaries as involving clear discontinuities such as 'like the separation between galaxies, solar systems, stars and planets' so that 'when we cross the boundaries we meet the interplanetary and intergalactic vacuum'. This vacuum however, far from being empty, is 'full of invisible matter and energy … [and crucially,] without the interplanetary and intergalactic vacuum there is no Universe'. (p.144).

In this context, Nicolescu (2008, p.10) has proposed three postulates or axioms constituting the methodology of transdisciplinarity, the 'combined action' of which 'engenders values' (Nicolescu, 2006a, p.154):

1. [The ontological axiom:] There are, in Nature and in our knowledge of Nature, different levels of Reality and, correspondingly, different levels of perception.
2. [The logical axiom:] The passage from one level of Reality to another is insured by the logic of the included middle.
3. [The complexity axiom:] The structure of the totality of levels of Reality or perception is a complex structure: every level is what it is because all the levels exist at the same time.

This methodology is clearly quite different from what Nicolescu terms Galilean scientific methodology,[3] and indeed does not seek to replace it but to incorporate and extend as appropriate (Nicolescu, 2006a, p.146). Indeed, and in particular given its genesis, the transdisciplinary methodology 'has the scientific spirit in its centre' (Nicolescu, 2012, p.4). In terms of the first axiom, different levels of reality can be found for example, when there is a discontinuity in applicable laws (e.g. Newtonian vs. quantum) and fundamental concepts (e.g. causality vs. indeterminate propensity), such for example, between the classical macrophysical world and the world of quantum physics. Apart from the quantum and physical, there also exist for example, the (bio)chemical, the biological, the psychological/self-conscious and the social. Moreover there is no hierarchy and there are no fundamental levels: 'no level of Reality constitutes a privileged place from which one is able to understand all the other levels of Reality' (Nicolescu, 2006a, p.147). Moreover as befits Gödelian incompleteness and the possibility of creative novelty 'every level is characterized by its *incompleteness*: the laws governing this level are just a part of the totality of laws governing all levels. And even the totality of laws does not exhaust the entire Reality: we have also to consider the Subject and its interaction with the Object' (p.147).

In the fashion of quantum indeterminism, the second axiom rejects the classical reductionist conception of the excluded middle which would hold envisage reality as comprising only in terms of an 'either/or' zero sum game (or at best, some compromise between both) i.e. as antagonistic opposites, with no room for a ('win-win' facilitating) creative middle ground (Nicolescu, 2006a, p.150). The 'included middle' or 'hidden third' of the second axiom, Nicolescu (2006b, p.13) contends, also characterises the zone between and outside respective levels of Reality, representing 'a zone of non-resistance to our experiences, representations, descriptions, images, and mathematical formulations', as one which is materially inaccessible 'due to the limitations of our bodies and of our sense organs', and which 'does not submit to any rationalization' (pp.11-12). It thus, he conceives, 'corresponds to the sacred' (p.12), in that it envisages reality *beyond* a hard materialistic construct and thus facilitates *creative* possibilities such as those expressed through for example, 'philosophy, art, politics, the metaphors concerning God, the religious experience and the artistic creative experience' (Nicolescu, 2006a, p.150).

A deeply problematic consequence of this then is that technoscience, and indeed neo-classical economics, which are each 'entirely situated in the zone of the Object' (Nicolescu, 2006a, p.157), are thus also entirely blind to the notion of *values*. Nicolescu (2004) argues therefore that unless or until there is a conciliation whereby 'scientific culture' is imbued with *values*, that is, it reconnects with 'humanist culture' and is thus transformed into a *true* culture, it is inherently incapable of generating productive dialogue with, for example 'cultures, religions and spiritual traditions'. This would maintain the continued cleavage between C.P. Snow's 'two cultures'. The consequences of this however, it is argued, are ultimately destructive to humanity (de Freitas, Morin and Nicolescu, 1994; Nicolescu, 2008, p.261).

Finally, with respect to complexity (dubbed the contemporary equivalent to the 'very ancient principle of universal interdependence' (Nicolescu (2006a, p.153)), Nicolescu notes that it is 'useful to distinguish between the *horizontal complexity*, which refers to a single level of reality and *vertical complexity*, which refers to several levels of Reality' (2006a, p.153). Transdisciplinarity, when practiced through the lens of vertical complexity (as outlined by for

[3] The principles of Galilean scientific methodology can be explained as: 1. There are universal laws, of a mathematical character; 2. These laws can be discovered by scientific experiment; 3. Such experiments can be perfectly replicated. (Nicolescu, 2006b, p.8, citing Galileo Galilei, 1956)

example, Morin (2008)) corresponds with the aforementioned 'strong transdisciplinarity' (Max-Neef, 2005).

Key to this conception of transdisciplinarity is the ontological restoration of appropriate recognition to the Subject, and more particularly the [Subject-Hidden Third-Object] agonistic and creative dialectic, ahead of the neo-Cartesian reductionist antagonistic [Subject vs. Object] 'either/or' dualism. This, Nicolescu (2006a, pp.142-143) argues, is at the heart of our global contemporary crises of (un)sustainability and is why a transdisciplinary informed methodology is not alone useful but a *sine qua non* for human progress:

> My line of thinking is in perfect agreement with that of Heisenberg. For me, "beyond disciplines" precisely signifies the Subject-Object interaction. The transcendence, inherent in transdisciplinarity, is the transcendence of the Subject. The Subject cannot be captured in a disciplinary camp. … Objectivity, set up as the supreme criterion of Truth, has one inevitable consequence: the transformation of the Subject into an Object. The death of the Subject is the price we pay for objective knowledge. The human being became an object – an object of the exploitation of man by man, an object of the experiments of ideologies which are proclaimed scientific, an object of scientific studies to be dissected, formalized, and manipulated. The relationship Man-God has become a relationship Man-Object, of which the only result can be self-destruction. The massacres of this century, the multiple local wars, terrorism and environmental degradation are acts of self-destruction on a global scale.

From this standpoint, transdisciplinarity approaches are not just apposite, but required across all our being. For as McGregor (2012, p.11) puts it, it is only:

> when the separate bits of knowing and perspectives, and the people who carry them, came together to dance in the fertile transdisciplinary middle space, they move faster when they are exposed to each other than when they are alone, creating intellectual fusion. The result is emergent, complex transdisciplinary knowledge (TD epistemology) that can be used to solve the pressing problems of humanity.

Bibliography

Barry, J. and Farrell, K. N., 2013. Building an Academic Career in the Epistemological no man's land. In: K. N. Farrell, ed. *Beyond Reductionism: A Passion for Interdisciplinarity.* London and New York: Routledge.

Bernstein, J. H., 2014. *Disciplinarity and transdisciplinarity in the study of knowledge.* [online] Available at: <http://www.inform.nu/Articles/Vol17/ISJv17p241-273Bernstein0681.pdf> [Accessed 10 June 2015]

Bourdieu, P., 1984. *Distinction: A social critique of the judgement of taste.* New York: Routledge.

Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D. J., Newig, J., Reinert, F., Abson, D.J. and von Wehrden, H. 2013. A review of transdisciplinary research in sustainability science. *Ecological Economics,* 92, pp.1-15.

Bursztyn, M. 2008. *Sustainability Science and the University: Towards Interdisciplinarity,* CID Graduate Student and Research Fellow Working Paper No. 24, February 2008. Center for International Development, Harvard University. [online] Available at:

<http://www.hks.harvard.edu/index.php/content/download/69125/1249310/version/1/file/024.pdf> [Accessed 1 September 2015]

Byrne, E. P. and Mullally, G., 2014. Educating engineers to embrace complexity and context. *Engineering Sustainability,* 167(6), pp.214-248.

Castán Broto, V., Gislason, M. and Ehlers, M., 2009. Practising interdisciplinarity in the interplay between disciplines: experiences of established researchers, *Environmental Science and Policy,* 12(9), pp.922-933.

Cilliers, P., 2007. The philosophical importance of thinking complexity. In: F. Darbellay, M. Cockell, J. Billotte and F. Waldvogel, eds. *Thinking Complexity: Complexity and Philosophy.* Mansfield: ICSE Publishing, pp.3-5.

Cilliers, P., 2008. Knowing Complex Systems: The limits of understanding. In: P. Cilliers, ed. *A Vision of Transdisciplinarity; Laying Foundations for a World Knowledge Dialogue.* Lausanne: EPFL and CRC Press, pp.41-50.

Cooper, G., 2013. A Disciplinary Matter: Critical Sociology. *Academic Governance and Interdisciplinarity, Sociology,* 47(1), pp.74-89.

Darbellay, F., 2015. Rethinking inter- and transdisciplinarity: Undisciplined knowledge and the emergence of a new thought style. *Futures,* 65,pp.163-174.

de Freitas, L., Morin, E. and Nicolescu, B., 1994. Charter of Transdisciplinarity. In: *1st World Congress of Trandisciplinarity.* [online] Available at: <http://ciret-transdisciplinarity.org/chart.php> [Accessed 1 August 2015].

Dockendorff, C., 2011. *The Long Way from Non-Reductionism to Transdisciplinarity: Critical Questions about Levels of Reality and the Constitution of Human Beings.* [online] Available at: <http://www.metanexus.net/essay/long-way-non-reductionism-transdisciplinarity-critical-questions-about-levels-reality-and> [Accessed 22 April 2015].

Du Plessis, H., Sehume, J. and Martin, L., 2014. *The Concept and Application of Transdisciplinarity in Intellectual Discourse and Research.* Johannesburg: MISTRA.

Fitzgerald, D. and Callard, F., 2015. Social Science and Neuroscience beyond Interdisciplinarity: Experimental Entanglements. *Theory, Culture & Society,* 32(1), pp.3-32.

Frodeman, R., 2014. Transdisciplinarity as Sustainability. In: K. Huutoniemi and P. Tapio eds. *Transdisciplinary Sustainability Studies: A Heuristic Approach.* London: Routledge, pp.194-209.

Fuchsman, K., 2009. Rethinking Integration in Interdisciplinary Studies. *Issues in Integrative Studies,* 27, pp.70-85.

Funtowicz, S. O. and Ravetz, J. R., 1993. The Emergence of Post-Normal Science. In: R. von Schomberg, ed. *Science, Politics and Morality.* Dordrecht: Springer, pp.85-123.

Galilei, G. 1956. *Dialogue on the Great World Systems.* Chicago: University of Chicago Press.

Gibbons, M, Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M., 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies.* London: Sage.

Gidley, J., 2013. Global knowledge futures: Articulating the emergence of a new meta-level field. *Integral Review,* 9(2), pp.145-172.

Giri, A. K., 2012. *Sociology and Beyond, Windows and Horizons.* Jaipur: Rawat Publications.

Gulbenkian Commission on the Restructuring of the Social Sciences, 1996. *Open the Social Sciences: Report of the Gulbenkian Commission on the Restructuring of the Social Sciences,* Stanford: Stanford University Press.

Häberli, R., Bill, A., Grossenbacher-Mansuy, R. and Klein, J.T., 2001. Synthesis. In: J. Thompson Klein, W. Grossenbacher-Mansuy, R. Häberli, A. Bill, R.W. Scholz and M. Welti, eds. *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society.* Basel: Springer.

Haribabu, E., 2008. The social construction of biotechnology: A transdisciplinary approach. In: B. Nicolescu, ed. *Transdisciplinarity: theory and practice.* Cresskill: Hampton Press, pp.191-200.

Hershock, P. D., 2010. Higher Education, Globalization and the Critical Emergence of Diversity. *Paideusis,* 19(1), pp.29-42.

Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U. and Zemp, E., 2008. *Handbook of Transdisciplinary Research.* London: Springer Dordrecht.

Hirsch Hadorn, G., Pohl, C. and Scheringer, M. 2002. Methodology of transdisciplinary research. In: G. Hirsch Hadorn, C. Pohl and M. Scheringer, eds. *Unity of knowledge (in transdisciplinary research for sustainability). Vol. II.* Paris: UNESCO-EOLSS. [online] Available at: <http://www.eolss.net/sample-chapters/c04/E6-49-02.pdf> [Accessed 1 October 2015]

Horlick-Jones, T. and Sime, J., 2004. Living on the border: knowledge, risk and transdisciplinarity. *Futures* , 36, pp.441-456.

Hukkinen, J. I. and Huutoniemi, K., 2014. Heuristics as cognitive tools for pursuing sustainability. In: K. Huutoniemi and P. Tapio, eds. *Transdisciplinary Sustainability Studies: A Heuristic Approach.* London: Routledge, pp.177-193.

Human, O. and Cilliers, P., 2013. Towards an Economy of Complexity: Derrida, Morin and Bataille. *Theory, Culture & Society,* 30(5), pp.24-44.

Jahn, T., Bergmann, M. and Keil, F., 2012. Transdisciplinarity: Between Mainstreaming and Marginalization. *Ecological Economics,* 79, pp.1-10.

Joas, H., 2004. The Changing Role of the Social Sciences: An Action-Theoretical Perspective. *International Sociology,* 19(3), pp.301-313.

Johnston, R. R., 2008. On connection and community: Transdisciplinarity and the arts. In: B. Nicolescu, ed. Transdisciplinarity: theory and practice. Cresskill: Hampton Press, pp.223-236.

Katunarić, V., 2009. Building sociological knowledge within and across disciplinary boundaries: megalomania vs. modesty?. *Innovation: The European Journal of Social Science Research,* 22, pp.201-217.

Klein, J. T., 2004. Interdisciplinarity and complexity: An evolving relationship. *E:CO,* 6(1-2), pp.2-10.

Klein, J. T., 2013. The Transdisciplinary Moment(um). *Integral Review,* 9(2), pp.189-199.

Klein, J. T., 2014a. Discourses of Transdisciplinarity: Looking Back to the Future. *Futures,* 63, pp.68-74.

Klein, J. T., 2014b. Interdisciplinarity and Transdisciplinarity: Keyword Meanings for Collaboration Science and Translational Medicine. *Journal of Translational Medicine & Epidemiology,* 2(2), pp.10-24.

Krishnan, A., 2009. *What are Academic Disciplines? Some observations on the Disciplinarity vs. Interdisciplinarity debate,* University of Southampton: ESRC National Centre for Research Methods.

Max-Neef, M. A., 2005. Foundations of transdisciplinarity. *Ecological Economics,* 53, pp.5-16.

McGregor, S. L. T., 2012. Place and Transdisciplinarity. In: *Transdisciplinarity and Sustainability.* Lubbock, Texas: TheATLAS Publishing, pp.8-12.

Mobjörk, M., 2010. Consulting versus participatory transdisciplinarity: A refined classification of transdisciplinary research. *Futures,* 42, pp.866-873.

Morin, E., 1999. *Homeland Earth.* Creskill: Hampton Press.

Morin, E., 2007. Restricted complexity, general complexity. In: C. Gershenson, D. Aerts and B. Edmonds, eds. *Worldviews, science and us: Philosophy and complexity.* Singapore: World Scientific, pp.5-29.

Morin, E., 2008. *On Complexity.* Creskill: Hampton Press.

Nicolescu, B., 1998. Gödelian Aspects of Nature and Knowledge. In: G. Altmann and W. A. Koch, eds., *Systems - New Paradigms for the Human Sciences.* Berlin: Walter de Gruyter, pp.385-403.

Nicolescu, B., 2004. Toward a methodological foundation of the dialogue between the technoscientific and spiritual cultures. In: L. Moreva, ed. *Differentiation and Integration of Worldviews.* Saint Petersburg: Eidos.

Nicolescu, B., 2006a. Transdisciplinarity – Past, Present and Future. In: B. Haverkort, ed. *Moving Worldviews - Reshaping sciences, policies and practices for endogenous sustainable development.* Leusden: COMPAS Editions, pp.142-166.

Nicolescu, B., 2006b. Transdisciplinarity – Past, Present and Future. In: B. Haverkort and C. Reijntjes, eds. *Moving Worldviews - Reshaping sciences, policies and practices for endogenous sustainable development.* Leusden: COMPAS Editions. [online version] Available at: <http://basarab-nicolescu.fr/Docs_articles/TRANSDISCIPLINARITY-PAST-PRESENT-AND-FUTURE.pdf> [Accessed 5 September 2015]

Nicolescu, B., 2008. *Transdisciplinarity: Theory and Practice.* Creskill: Hampton Press.

Nicolescu, B., 2010. Methodology of Transdisciplinarity: Levels of Reality, Logic of the Included Middle and Complexity. *Transdisciplinary Journal of Engineering and Science,* 1(1), p.19-38.

Nicolescu, B., 2012. *Transdisciplinarity and Sustainability.* Lubbock: TheATLAS Publishing.

Nowotny, H., Scott, P. and Gibbons, M., 2003. Introduction: `Mode 2' Revisited: The New Production of Knowledge. *Minerva,* 41(3), pp.179-194.

Nzi iyo Nsenga, F. X., 2008. Design studies: A transdisciplinary perspective. In: B. Nicolescu, ed. *Transdisciplinarity: theory and practice.* Cresskill: Hampton Press, pp.237-244.

O'Reilly, K., 2009. For interdisciplinarity and a disciplined, professional sociology. *Innovation: The European Journal of Social Science Research*, 22(2), pp.219-232.

Peters, S. and Wals, A., 2013. Learning and Knowing in Pursuit of Sustainability: Concepts and Tools for Transdisciplinary Environmental Research. In: M. Krasny and J. Dillon, eds. *Trading Zones in Environmental Education: Creating Transdisciplinary Dialogue.* New York: Peter Lang, pp.79-104.

Piaget, J., 1972. L'épistémologie des relations interdisciplinaires. In: L. Apostel, G. Berger, A. Briggs and G. Michaud, eds. *Interdisciplinarity: Problems of teaching and research in universities.* Paris: OECD, pp.127-140.

Pohl, C., 2008. From science to policy through transdisciplinary research. *Environmental Science and Policy,* 11, pp.46-53.

Pohl, C., 2010. From Transdisciplinarity to Transdisciplinary Research. *The Atlas Transdisciplinary Journal of Engineering & Science,* 1, pp.74-83.

Ramadier, T., 2004. Transdisciplinarity and its challenges: the case of urban studies. *Futures,* 36, pp.423-439.

Rau, H. and Fahy, F., 2013. Sustainability Research in the Social Sciences: Concepts, Methodologies and the Challenge of Interdisciplinarity. In: F. Fahy and H. Rau, eds. *Methods of Sustainability Research in the Social Sciences.* London: Sage, pp.3-24.

Repko, A. F., 2012. *Interdisciplinary Research: Process and Theory.* 2nd ed. London: Sage.

Robinson, J., 2008. Being undisciplined: Transgressions and intersections in academia and beyond. *Futures,* 40, pp.70-86.

Schiemann, G., 2011. An epoch making change in the development of science? A critique of the epochal-break-thesis. In: M. Carrier and A. Nordmann eds. *Science in the Context of Application.* Heidelberg: Springer, pp.431-453.

Shrivastava, P. and Ivanaj, S., 2012. Transdisciplinary Art, Technology, and Management for Sustainable Enterprise. In: B. Nicolescu, ed. *Transdisciplinarity and Sustainability.* Lubbock: TheATLAS Publishing, pp.112-128.

Stock, P. and Burton, R. J. F., 2011. Defining Terms for Integrated (Multi-Inter-Trans-Disciplinary) Sustainability Research. *Sustainability,* 3, pp.1090-1113.

Wallerstein, I., 2004. The three meanings of "discipline". In: *Re-inventing the Social Sciences.* Paris: OECD, pp.22-25.

Webb, J., 2006. When 'Law And Sociology' Is Not Enough: Transdisciplinarity and the Problem of Complexity. In: M. Freeman, ed. *Law and Sociology: Current Legal Issues 2005.* Oxford: Oxford University Press, pp.90-106.

Wellbery, D. E., 2009. The General Enters the Library: A Note on Disciplines and Complexity. *Critical Inquiry,* 35(4), pp.982-994.

Wickson, F., Carew, A. L. and Russell, A. W., 2006. Transdisciplinary research: characteristics, quandaries and quality. *Futures,* 38, pp.1046-1059.

Yeats, W. B., 1920. *Michael Robartes and the Dancer.* Dublin: The Chuala Press.