

SCIENTIFIC CONTRIBUTIONS (Wetenskaplike Bydraes)
SERIES H: INAUGURAL ADDRESS: NR. 254

TRANSDISCIPLINARITY:
THE BINDING PARADIGM FOR DISASTER
RISK REDUCTION

Prof Dewald van Niekerk

It all starts here



NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

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**TRANSDISCIPLINARITY:
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INTRODUCTION

The need of human beings to be safe from harm has been well documented and researched (Maslow, 1968). According to the Christian faith, after creation, God instructed man to rule over all the earth (Bible, 1996). Since this commandment, humans have been in constant contact with the natural cycles, processes and systems of the earth. Some of these cycles and processes proved, in time, to be harmful to every living thing and the environment on which we depend. These natural hazards had variable impacts on the normal way of life of the various civilisations and societies. The development and progression in humankind's understanding of the world and life ensured a progressive and continuous evolution in the response to the events threatening our livelihood. Humankind developed techniques to deal with natural hazards, either by aiming to contain the forces of nature, or by altering our own behaviour. The development of humankind brought with it an increase in the susceptibility towards hazardous exploitation. It was only in the modern age that humankind aimed to study and understand what was called "natural disasters". This study increased our understanding of the causal factors and the ways in which humans contribute to their own demise through unsustainable development practices.

During the last century, several powerful natural disasters occurred in different parts of the world, in both technologically advanced and developing countries. The types of natural hazards that triggered these disasters varied from the unpredictable occurrence of earthquakes and tsunamis, to more predictable seasonal floods, periodic storms and heat waves. Other less immediate, slowly evolving and sometimes smaller compounding hazards such as recurring seasonal veld fires, drought and environmental degradation have affected even more people with potentially greater costs for their future and livelihoods. More than anything else, the media images of natural disasters at the close of the twentieth century underscored and focussed upon the human consequences and social dimensions of these events (see the work of Olsen *et al*, 2003 and Schmeidl and Jenkins, 1998 in this regard).

However, the progression and evolution of the study of natural hazards and their effects has long progressed beyond a pure focus on the consequences of disasters and the human reaction to them.

The tide has shifted to a much more intangible and sometime less understood phenomenon which we now call disaster risk. Disaster risk, and risk in general, is an abstract concept. It has various meanings in different contexts (e.g. financial risk compared to agricultural risk).

In this paper, the focus is on the possible contributions of many disciplines to the concept of disaster risk through a transdisciplinary paradigm. Using transdisciplinarity as paradigm reference to a number of theories, models and tools in many disciplines will show how each has a unique contribution to make to the field of disaster risk reduction.

THE STUDY OF DISASTER AND RISK

The focus on disaster and risk came about through various initiatives and events since the Second World War. The *scientific* study of disaster and risk is one such event. A focus on the development of disaster risk reduction would however be incomplete without a discussion of the roots of disaster studies and research both within the social as well as natural sciences.

Some of the earliest recorded ideas on disaster and risk within the social sciences were expressed by the likes of Prince (1920), Carr (1932) and Sorokin (1942) who questioned the influence of catastrophe on social patterns. Although these authors were known to some in this field of study, they were seldom explicitly acknowledged for their pioneering work (Quarantelli, 1998:1), and they greatly influenced the subsequent works by others in disaster studies. Some of the first systematic work in disaster studies and research occurred in the 1950s (Endelman, 1952; Powell, Rayner & Finesinger, 1952; Quarantelli, 1954 & 1957; Moore, 1956; Fritz & Williams, 1957) and 1960s (Drabek & Quarantelli, 1967; Dynes & Quarantelli, 1968), with a noticeable heightened interest in the 1970s (Doughty, 1971; Hewitt & Burton, 1971; Kreps, 1973; Dynes, 1974; Mileti, Drabek & Haas; 1975; Glantz, 1976; Westgate & O'Keefe, 1976; O'Keefe, Westgate & Wisner, 1976; Jager, 1977; Torry, 1978; Turner, 1978). These earlier theorists and researchers approached the concept of disaster from a social science as well as a natural/physical science perspective. It is also evident in this period (1970s) that European scholars were much more interested in this phenomenon than their American counterparts. The enormous contribution of American social science scholars since the 1980s can, however, not be denied.

Gilbert (in Quarantelli, 1998) indicates that the social science perspective approached the study of disaster from three different paradigms: content research, chronological development and lastly, cleavages. In the first instance, disaster was viewed as a duplication of war - an external agent can

be identified which requires communities to react globally against the “aggression”. The second (chronological development) viewed disaster as an expression of social vulnerability – disaster is therefore the result of underlying community logic or social processes. Thirdly, disaster was an entrance to a state of uncertainty – disaster is the impossibility of identifying and defining (real or perceived) dangers. It is therefore an attack on our perception and known reality. Cardona (2003) and Kreps (in Quarantelli, 1998) believe that the above early paradigms within the social science emphasised the reaction and perceptions of communities during and after emergencies and did not explicitly focus on issues of risk, or mitigating the risk of physical harm and social disruption before an event had occurred.

The natural and physical science approach to disaster emphasised the hazard component in terms of hydrometeorological, geodynamic and technological/anthropogenic phenomena such as earthquakes, floods, mudslides, cyclones, industrial accidents and nuclear fallout. The natural sciences therefore aimed to understand the dynamics of hazards (Smith, 2002; Cutter, 1994) and from this standpoint tried to quantitatively determine (and simulate) its possible occurrence and impact on humans and the environment. Dombrowsky (in Quarantelli, 1998) cautions that although this approach has proven to be scientifically sound, it is impossible to recreate reality based on algorithms that simulate changes over time exactly. Beside understanding the causal factors of natural hazards (such as applying the theory of fluid dynamics to understand meteorology and ocean dynamics - Pedlosky, 1982), significant research has been aimed at finding human-led solutions to mitigating the impact of hazards, such as better building techniques (see for instance the work of Bazant and Cedolin, 2010).

Gilbert (1995) proclaims that the scientific approach to disaster and risk is in many instances a reflection of the “market” in which disaster research became an institutional demand. The historical disaster (and risk) studies literature tended to focus on “*how the rich nations feel*” (Sachs, 1990) and did not necessarily address the social, economic, and political realities in poorer countries most affected by disasters and risk. The natural sciences were, however, the first to address issues of probability and risk, based on quantifiable hazard variables. Moreover, the focus on risk (as apposed to disaster) as a social phenomenon became evident during the latter part of the 1970s. In the 1980s, a global realisation developed that disaster is not so much the size of the physical event but the inability of the stricken community to absorb the impact within its proper set of constraints and capacities (Lechat, 1990; Lavell, 1999). This realisation highlighted the need towards a risk, rather than disaster focus in disaster studies and research.

The modern-day study of risk relates closely to the first understanding and investigation of disaster, within both a social and natural/physical science perspective, as explained above. Cardona (2003), Kelman (2003) and Smith (2002) identify two schools of thought that have developed in terms of disaster risk since the 1980s. Cardona refers to these as the *constructivist* and *objectivist* or *realist*) schools of thought. Smith's interpretation is that of *behavioural* and *structural* paradigms. Kelman simply refers to the social scientist and physical scientist's focus on risk. After assessing the work of the three authors, it became clear that for all means and purposes the constructivist school of Cardona, the behavioural paradigm of Smith and the social scientist focus by Kelman refer to the same approach in the investigation of disaster, so too the objectivist, structural and physical scientist paradigms. The work of Cardona will be used to differentiate between these two aspects.

Constructivist thinking relates to social sciences where risk is viewed as a social construct (similar to the earlier disaster focus). This approach requires an understanding of social representations and perceptions, and the interaction between different social actors and phenomena. A consciousness developed that it is conditions of risk, and the attitudes to risk, rooted in societies that inevitably lead to disasters. These conditions and attitude to risk in Less Developed Countries (LDCs) are greatly dependent on the economic conditions of a given country. Such conditions necessarily force vulnerable societies (e.g. the poor) to accept the risks which they face, whereas rich societies can choose to avoid such risks. On the other hand, the objectivist or realist school finds itself more within the natural and physical sciences. Within this school of thought, it is believed that risk can be quantified and objectively judged. As with the earlier emphasis on the quantification of disaster, so the accent within the natural and physical science remained on the quantification of risk. This estimation of risk also translated to the economic and actuarial sciences that believe that risk can be determined through mathematical formulae. Hewitt (in Quarantelli, 1998), a geohazard scientist, acknowledges that the social understanding of disaster is much more crucial to the contemporary disaster/risk scene.

It would be unjust to assume that both of the mentioned schools of thought or paradigms enjoyed equal status within the international arena. Hewitt (in Quarantelli, 1998) says that the pure focus on the social construct of disaster/risk by the constructivists ignores the hazard or "*agent-specific*" approach. This approach remained the most common vision of disasters, even in the work of social scientists within the 1980s. The truth to this statement is evident in the objectives of the International Decade for Natural Disaster Reduction (IDNDR). Both of these schools of thought have made the paradigm shift from a pure disaster oriented focus to that of disaster risk. The

contemporary understanding of risk has greatly increased to the extent that various scholars from a variety of different disciplines (e.g. sociology, anthropology, geography, architecture, agriculture, meteorology, engineering, law, public administration and development studies) are jointly researching issues of disaster risk (Comfort *et al*, 1999; Vogel, 1999).

With the above in mind, one could thus question the current trajectory of the knowledge creation within the domain of disaster risk studies to the extent that some (Van der Walddt, 2012) are arguing for the maturity of the focus into an academic discipline. This paper will try to show and argue against the development of the focus of disaster risk reduction into a traditional academic discipline (although it might be inevitable). This will be achieved by firstly focussing on traditional knowledge creation, research paradigms and traditional disciplines. A conceptual understanding of the terms multi-, pluri- and interdisciplinary research will be provided, and in doing so explain knowledge creation through disciplinary interaction. Thereafter, the pillars and laws of transdisciplinarity will be considered and it will be argued that it is only through a transdisciplinary paradigm that one can make a meaningful contribution to understanding and reducing the phenomenon known as disaster risk.

DISASTER RISK

Risk has various connotations within different disciplines. In general, risk is defined as “*the combination of the probability of an event and its negative consequences*” (UNISDR, 2009). The term risk is, however, multidisciplinary and is used a variety of contexts (see the work of Bouchaud and Potters, 2003 on financial risk; Monagan, 2008 on enterprise wide risk management; Boisvert and McCarl, 1990 on agricultural risk; Chapman and Ward, 2003 on project risk management; Pritchard, 2000 on environmental risk management; and Sunderkötter, 2004 on software engineering risk management to name but a few). Risk is usually associated with the degree to which human cannot cope (lack of capacity) with a particular situation (e.g. natural and anthropogenic hazard) (UNISDR, 2009).

The term disaster risk therefore refers to the potential (not actual and realised) disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or society over some specified future time period (UNISDR, 2009). Disaster risk is the product of the possible damage caused by a hazard due to the vulnerability within a community. It should be noted that the effect of a hazard (of a particular magnitude) would affect communities differently (Von Kotze, 1999). This is true because of the varied levels of the coping mechanisms within

communities. Poorer communities are therefore more at risk than communities that do have the capacity, access to resources and assets to cope.

Risks exist, or are created within social systems. The social context in which risk occurs is an important consideration. It should also be noted that people would therefore not share the same perceptions of risk and their underlying causes due to their social circumstances. To understand risk perception one can learn and borrow from the work of Hoffman (2009) on theories of perception. To determine disaster risk three aspects need to be present: a hazard, vulnerability to the hazard and some form of coping capacity.

Risk as an abstract term has various meanings across cultures and linguistic boundaries. One such example, which is widely cited by many disciplines, is the traditional Chinese meaning of danger (equated to “risk”): “*Wei-Ji*” (depicted in Figure 1 below) said to represent both “danger” and “opportunity”. However, Mair *et al.* (2009) shows how a misunderstanding of the traditional

The image shows the Chinese characters '危机' (Wei-Ji) in a large, bold, black font. The characters are '危' (left) and '机' (right). The '危' character is composed of '厃' (top) and '卩' (bottom), while the '机' character is composed of '木' (left) and '几' (right).

Mandarin has led many astray to the extent that reference to *Wei-Ji* (danger and opportunity) can even be found in academic literature.

Figure 1: Mandarin characters for “crisis”: *Wei-Ji*

This illustration aims to show the complexity of the term risk and how its interpretation can lead to various applications and ontology. That said: does a wrong interpretation of an ancient term necessarily lead to wrongful actions? In this example one could argue that the wrongful interpretation literally provides an “opportunity” for action, rather than inaction. Similarly in Nguni languages there exists no words for “risk”, “disaster”, “danger”. However, the word “*ingozi*” has the connotation of all above. The varied understanding and interpretations, in turn, have an influence on how knowledge is understood, created and researched. Lexicology, thus, becomes very relevant in understanding the deeper meaning of words, which relate to disaster risk and risk changing behaviour, and their nature.

Should one agree that risk is a social construct, then it becomes important to consider the various paradigms in which knowledge is created and how this relates to new paradigms of understanding reality, knowledge and values. This in turn will allow for a better understanding of the transdisciplinary paradigm and how it provides fertile soil in which a better comprehension of disaster risk by all disciplines can be cultivated.

DOMINANT WESTERN PARADIGMS

One of the most quoted definitions of paradigm is that of Thomas Kuhn's (1962, 1970) in *The Nature of Science Revolution*. He states that a paradigm is the underlying assumptions and intellectual structure upon which research and development in a field of inquiry is based. Patton (1990) is of the opinion that a paradigm is a worldview, a general perspective, a way of breaking down the complexity of the real world. Guba (1990) views paradigm as an interpretative framework, which is guided by "a set of beliefs and feelings about the world and how it should be understood and studied." (Chilisa, 2011) adds axiology (values) as another category, which influences beliefs. Denzin and Lincoln (2001) in turn list three categories of those beliefs:

- *Ontology*: what kind of being is the human being? Ontology deals with the questions of what is real, and what is reality.
- *Epistemology*: what is the relationship between the inquirer and the known? "[E]pistemology is the branch of philosophy that studies the nature of knowledge and the process by which knowledge is acquired and validated" (Gall, Borg and Gall, 1996).
- *Methodology*: how do we know the world, or gain knowledge of it?

Two of the dominant Western doctrines and traditions are positivism and anti- or post-positivism (also called "interpretivism"). Positivism emphasises that the logical and mathematical treatment of data is the only way to authoritative knowledge. Knowledge is thus based on empirical evidence, which can be verified and recreated. It assumes that society operates according to a set of laws, which are valid and constant. Post-positivists believe that the social world is not subject to the same methods of investigation as the natural world. It focuses on understanding the interpretations that social actions have for people being studied. A third, less well known doctrine, which is also worth mentioning, is that of *transformatism*. With its roots in Darwinism, transformatism holds that we can change and learn, transform and evolve according to our experiences. Table 1 below is a synopsis of the various categories associated with these paradigms.

Table 1: Dominant Western paradigms

Paradigm	Positivism	Post-positivism	Transformativism
Ontology	Two-world theory: The “natural” vs. “social”: Two different realities; natural is more “real”; it exists independently of our perceptions.	Two-world theory: social world = exist independently of ourselves: multiple realities within the “social”.	Socially constructed world: filled with structural injustices, inequalities, asymmetries.
Epistemology	Subject/object primacy of the object realism; empiricism; disciplinary divide between natural vs. social.	Primacy of the constituting subject: our different perceptions constitute different “realities”: meaning vs. truth.	Generating knowledge through changing the social conditions determining our thinking; learning by doing.
Anthropology	Mind-body duality; reason: <i>cogito ergo sum</i> ; human senses to be brought under control by reason.	Consciousness, language, symbolic expressions are what differentiates humans from non-humans.	We are continuously constructing and being constructed by our social world.
Axiology	Value-free science: social and personal “values” should not interfere with knowledge production.	Value-free science is possible: every act of interpretation – including scientific – is value-laden; thus, value explication is important.	Justice; equality; fairness; only change in the social order / status quo will bring about a change in values.
Methodology	Quantitative Analysis; decoupling; falsification; generalising; reducing; abstracting; explaining.	Qualitative Embedding; specificity; (inter) subjectivity; experience; perceptions.	Transformative Inequalities; asymmetries; power-knowledge and social relations.
Methods	Quantitative Experiment; modelling; statistical analysis; Bayesian networks; surveys	Qualitative Ethnography; narratives; participative observation; discourse analysis.	Transformative Participatory Action Research; Community-based Participatory Action Research; Phronetic Planning.

(Source: Van Breda, 2012)

The focus on disaster risk reduction as a transdisciplinary issue must, however, be contextualised by applying the third law of transdisciplinary (see section below), which is to say, explain what it is not. Therefore, the differences between disciplinary, pluri-, inter- and multidisciplinary will be discussed in the section to follow and in doing so highlight what disaster risk reduction is not.

DISCIPLINARY, PLURI-, INTER-, AND MULTIDISCIPLINARY INTERACTIONS

From the onset one needs to acknowledge that, as Nicolescu (2002) puts it: “Disciplinarity, multidisciplinary, interdisciplinarity and transdisciplinarity are like four arrows shot from but a single bow: knowledge.” The aim of this paper is thus not to argue for or against any of these knowledge creation and exploration methods, rather a brief discussion of each facilitates a better understanding of transdisciplinary.

Disciplinary research concerns in most cases the same level of Reality. At best, disciplinary research only concerns fragments of one level of Reality. It is thus very specific within a selected domain and focusses very narrowly on phenomena (Krishnan, 2009). Each discipline has its own interpretation of ontology, epistemology, anthropology, etc. (see Table 1 above). Disciplinary research allows one to become an expert in a specific field of study, which is also mostly linked to a profession (Hyland, 1999). Little to no cross-pollination from other knowledge areas occur and this level of research is mostly concerned with the expansion of its own body of knowledge.

Pluridisciplinarity involves studying a research topic not in only one discipline but in several at the same time (Max-Neef, 2005). This could entail, for example, studying the causes of poverty, or the use and application of water from either a sociological, educational, hydrological, economical, political, geographical or even cultural perspective. Pluridisciplinarity does not in all cases assume that these various disciplines are working together in a coherent manner.

Multidisciplinarity brings an addition to the discipline in question (e.g. the history of water or economics of households). One should be mindful that this addition is mostly in the exclusive service of the home discipline (Max-Neef, 2005). In other words, the multidisciplinary approach overflows disciplinary boundaries, while its goal remains limited to the framework of disciplinary research.

Interdisciplinarity has a distinct different goal from multidisciplinary. It concerns the transfer of methods from one discipline to another. For example, the Game theory has successfully been applied in various disciplines although it has its origins in economics. Similarly there is an increasing interest in using social science methods, theories and models to assist in understanding the human factor linked to environment issues (e.g. social impact assessments) (Becker, 2001; Becker & Becker, 1997). With the above explanation in mind, it is prudent to focus on transdisciplinarity and how this is understood in terms of disciplinary relations.

TRANSDISCIPLINARITY

As universities evolved, disciplines became more complex and fragmented. Today we have a multitude of disciplines, sub-disciplines and even sub-sub-disciplines. Academia has become painfully specialised. Moreover, university administrators are purposefully steering universities towards inculcating a more entrepreneurial spirit (Thorp and Goldstein, 2010). This requires new and innovative solutions to the pressing problems of the Globe, and new ways in which various disciplines can work together. For example, uncertainties linked to climate change and climate variation have a direct and profound effect on the level of disaster risk, which communities might face in the future. Already there is substantial evidence of the impact of climate change on at-risk communities (Thomalla *et al.* 2006; Schipper, 2007; Mercer, 2010). However, the solution to climate change is not limited to the climate science of disaster risk reduction domain. Climate change, as disaster risk reduction, is a multi-sectoral and multidisciplinary phenomenon. A problem which, as stated above, remains in direct contrast with the continuing structure of universities into faculties and disciplines. The paradox of fostering entrepreneurialism, yet not paying attention to the structure which inhibits it, is undeniable.

Transdisciplinarity, although called "*an unfinished scientific programme*" by Max-Neef (2005), "*offers some fascinating possibilities for advanced reflection and research*". It is thus my argument in the sections to follow that, although not a final and complete research paradigm, a transdisciplinary focus on disaster risk reduction problematic opens new opportunities to solving disaster risk reduction issues.

Pohl and Hadron (2008) believe that transdisciplinarity is needed "*when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them. Transdisciplinary research deals with problem fields in such a way that it can: a) grasp the complexity of problems, b) take into account the diversity of life-world and scientific perceptions of problems, c) link abstract and case-specific knowledge, and d) develop knowledge and practices that promote what is perceived to be the common good*". Nicolescu (2002) says that as the prefix "trans" indicates, transdisciplinarity concerns that are, at once, between the disciplines, across the different disciplines, and beyond all disciplines. Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge.

Table 2: Transdisciplinary paradigm

Paradigm	Transdisciplinary
	Crosses disciplinary boundaries to create holistic approach – uses concepts and methods originally created in other disciplines. Relates scientific knowledge to problem solving.
Ontology	Social / human systems are different to natural / ecological / environmental systems, but they have become inextricably coupled / interconnected.
Epistemology	Co-producing of knowledge; collaborative; participatory; mutual learning; uncertainty.
Anthropology	The humans (the “social”) are different from nonhumans (the “natural”) but are inextricably entangled.
Axiology	Equal value of disciplinary and non-disciplinary knowledge systems (when facing complex real-world problems).
Methodology	Integrating; bringing together; synthesizing; merging.
Methods	Integrative methods: conceptual clarification; theoretical framing; research questions; hypothesis formulation; assessment measures; etc.

(Source: Van Breda, 2012)

Widely accepted throughout the scientific community working transdisciplinary are the three fundamental pillars as alluded to by Nicolescu (2002). These pillars (levels of Reality, the logic of the included middle and complexity) also determine the methodology of transdisciplinary research.

PILLARS OF TRANSDISCIPLINARITY

Reality in essence means: “the world, or state of things as they actually exist” (Anon n.d.), as opposed to how they can be imagined or may appear to be. Max-Neef (2005) indicates that reality is that which resists our experiments, representations, descriptions, images or mathematical formalizations. In transdisciplinarity, the *levels of reality* is a never changing set of systems with respect to the actions of general laws. One can thus argue that these laws break down when transcending from one reality to the next. For example a thought about conducting a violent crime and the actual act represent two different realities, governed by distinct and different laws. In quantum physics, the behaviour of light in certain conditions (e.g. particles vs. waves or light travelling through water vs. air) is another example (see the work of Einstein and Planck in his regard) (Spring & Davidson n.d.). Max-Neef (2005) aptly says that “what appears to be increasingly evident is that we can no longer assume that there is just one reality, fully describable and understandable in terms of pure reason”.

The second pillar of transdisciplinarity is the *logic of the included middle*. Niels Bohr, a well-known Danish physicist, had the motto '*Contraria sunt complementa*' - opposites are complementary. His motto explains the essence of this second pillar, which means that wholeness leads to clarity. Thus opposites in realities must be seen as inclusive and not exclusive (e.g. day and night, logic and intuition, spirit and physique). The logic of the included middle becomes evident once one investigates phenomena from different cultural backgrounds. Understanding spirituality and religion is quite different from a Western vs. an Eastern vs. an African perspective. Although sometimes opposites, the investigation of both sides leads to new knowledge and understanding. Similarly, light can be a wave and particle, depending on the reality from which it is investigated. In transdisciplinarity, this pillar aims to explain the convergence of ontologies. "Knowledge is neither interior nor exterior; it is at the same time interior and exterior. The study of the Universe and the study of human beings sustain each other" (Nicolescu, 2002).

The last pillar as explained by Nicolescu (Nicolescu, 2002) is that of *complexity*. Complexity and the study of complex and chaotic systems is not new, and has been used in various disciplines (see the work of Lorenz, 1963; Thietart and Forgues, 1995; Kiel and Elliott, 1997). Moreover we have seen complexity and chaos, and non-linear process in many areas of science. For example, Max-Neef (2005) says that "there are overwhelming evidences today, that the way in which economics is taught in the Universities, and practiced in real life, is incapable of solving the problems with which it is concerned, and which, after all, justify its existence as a discipline." Our relation with a complex world and complex systems cannot be explained by traditional linear logic. Our systems and world are chaotic. To understand, and wagger to explain this complexity, one could look at the work of meteorologist Edward Lorez (arguably the father of chaos theory). Lorenz holds that chaos theory is "the qualitative study of unstable irregular behaviour in deterministic nonlinear dynamical systems" (Lorenz, 1963). He proposes six characteristics of chaos and complexity:

- a. System is dynamic, which means it changes over time.
- b. Behaviour of the system is aperiodic and unstable (does not repeat itself).
- c. Although chaotic behaviour is complex, it can have simple causes.
- d. The nonlinear characteristic of the system makes it sensitive to initial conditions (nonlinear = output of system is not proportional to the inputs - the whole is not equal to the sum of its parts).
- e. Chaotic behaviour is not random although it is aperiodic and unpredictable because the system is deterministic.

f. Output of the system is used as the input in the next calculation/iteration.

An understanding of chaos and complex system would be almost impossible from a uni-disciplinary perspective, and difficult from a pluri- or even multidisciplinary perspective. It thus stands to reason that only through inter- and transdisciplinarity can complex systems be fully understood, and solutions to societal complexity such as poverty, unemployment, sustainability and disaster risk be found.

Although the pillars of transdisciplinary explain the logic of the paradigm, Max-Neef (2005) proposes three laws of transdisciplinarity.

LAWS OF TRANSDISCIPLINARITY

Max-Neef's first law says that "the laws of a given reality are not sufficient to describe the totality of phenomena occurring at that level." This is evident through the application of chaos and complex systems theory to various realities. Secondly, "every theory at a given reality is a transitory theory, since it inevitably leads to the discovery of new contradictions situated in new level of reality." This second law allows an understanding of the evolution of knowledge. Applying the second law means that knowledge remains forever an open system, without a unifying theory as an end product. Thirdly, and possibly most abstract, Max-Neef (taking from the father of Taoism, Lao Tzu) believes that "only because of what is not there, it is possible that there is what is there; and only because of what is there it is possible that there is not what is not there". It is in this last law that all three pillars of transdisciplinary becomes evident: levels of Reality, logic of the included middle and complexity.

CONCLUSION

Transdisciplinarity, more than a new discipline or super-discipline is, actually, a different manner of seeing the world, more systemic and more holistic (Max-Neef, 2005). In order for disaster risk reduction to have any effect, it requires a vast number of disciplines to find numerous solutions to real world problems, through a transdisciplinary paradigm. This relatively new way of knowledge creation will serve both the intuitive and rational mind well. Transdisciplinary provides a binding paradigm for disaster risk reduction.

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