7/31 – Transdisciplinary Logics of Complexity

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Introduction

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Transdisciplinarity (TD) has evolved over the last 40 years as a way to grapple with the complex, wicked problems facing humanity (McGregor, 2015; Nicolescu, 2014). Examples include health inequality, climate change, unsustainability, loss of diversity, poverty, uneven development, and unequal income and wealth distribution. *Trans* takes us beyond *multi* (more than one) and *inter* (between, among) disciplinarity, which are confined to university academic disciplines. *Trans* means across and beyond to a new space (Harper, 2020) where new knowledge is made from combined disciplinary and life-world knowing (i.e., government, business, and civil society). The transdisciplinary approach to knowledge creation was developed to address social, political, environmental, economic and technological problems that resist resolution using just disciplinary knowledge (Nicolescu, 2002, 2014).

A point of fact – complex transdisciplinary problems cannot be completely solved; they can only be addressed. To address a problem entails directing attention and resources to it so it can be better understood, preparing people to begin to deal with it (Stuart, 2018). Complexity thinking and complexity logic are needed to reason through and address transdisciplinary problems, because they are complex and wicked (Desbois, 2012; Liang, 2017; Nicolescu, 2002, 2014), to be discussed.

This paper teases out this unique type of logic so it will be easier for others to employ – beginning with an overview of complex wicked problems. The thinking and reasoning needed to address these problems will require logic that can deal with complexity. After defining logic in general, traditional classical logic and laws of thought are described. Their inability to deal with complexity led to scholarly work on the logics of complexity and the need for a complexity mindset (Liang, 2017; Nicolescu, 2014). The "logic of complexity can be used to understand the problem space (better, the space of possibilities) when addressing seemingly intractable problems and create coevolving enabling environments and more positive futures" (Serrat, 2017, p. 352).

Complex Wicked Problems

This section distinguishes among a problem, a *complex* problem, and a complex *wicked* problem. Conflating them in discussions of transdisciplinarity short circuits people's appreciation of how they differ and the reality that wicked problems merit a unique approach.

Problem

Problem is Greek *problema*, "put forth; that which is proposed" (Harper, 2020). A problem is a question, matter, task, discrepancy or stimulus for which its explanation or how to address it is not immediately known (Costa & Kallick, 2000). A problem "is a matter or situation regarded as unwelcome, harmful or wrong and needing to be overcome" (Maddox, 2015, para. 13). It is a difficult situation that must be addressed. Problems manifest when "humans experience dichotomies, are confused by dilemmas, or come face to face with uncertainties" (Costa, 2020, para. 2). These three scenarios all encompass doubt about how to proceed, because a misguided or ill-advised decision can have dramatic, sometimes life altering, consequences.

Complex Problem

Complex problems differ from simple and complicated problems. Simple problems can be solved with previously used, standardized solutions with similar, positive results (e.g., baking a cake). Complicated problems can be solved using high levels of expertise from a variety of fields to apply formulae and standards with the expectation that what worked before will work again with predictable results (e.g., building a bridge) (Stuart, 2018).

In contrast, *complex* problems (made up of many interwoven, different, parts) can be approached "from multiple, sometimes competing, perspectives and may have multiple possible solutions" (Penn State, 2020, para. 1). They cannot be solved with formulae or standardized approaches. What worked in one situation may not work again. High levels of expertise can be helpful but are not sufficient. The outcomes are uncertain and are considered to be better or worse rather than right or wrong (Rittel & Webber, 1973; Stuart, 2018) (e.g., addressing inner city poverty and crime).

Complex Wicked Problem

Complex problems become *wicked* when they are "highly resistant to resolution" (Australia Public Service Commission, 2007, p. 1) (e.g., saving the Amazon rain forest or stopping desertification caused by deforestation or inappropriate agriculture naively thought to ensure prosperity). But "complexity itself is not enough to trigger a wicked problem… [They are triggered when] serious disagreements among stakeholders are combined with complexity and uncertainty [wherein] we have crossed a threshold" (Head, 2008, p. 103). The problem has shifted from complex to wicked, which is Middle English *wikked*, "bad" (Harper, 2020).

Trying to solve wicked problems creates even more problems (some of *them* wicked), but something *must* be done. Wicked problems are messy, vicious and aggressive. They are context unique, hard to define and unpredictable with many disparate stakeholders vying for a voice in their problematization and resolution. These people bring very different world views and perspectives to the table and tender radically different opinions about possible causes and cures. Consequences (intended or not) of any actions considered or taken are not known beforehand (McGregor, 2012, 2019; Rittel & Webber, 1973; Stuart, 2018). At the time of writing, the Coronavirus COVID-19 had emerged as a profoundly complex wicked problem with inconceivable, long-lasting consequences. Never has the whole world been shut down (Berinato, 2020).

Complexity

Complex is an interesting word. It is more than just simple (Latin *simplus*, "plain and uncomplicated). Complex is Latin *complexus*, "plaited, interlaced strands, intertwined, embraced" (Harper, 2020). The opposite of complex is *not* simplicity (i.e., few parts or easy to understand) but that which is not woven; noncomplex means independent and not connected (Alvira, 2014a, b). Complexity is nonlinear, meaning the interwoven strands are defined in relation to what they are connected. Nonlinearity also means the whole is *different* from the sum of all of the parts (e.g., a cake made from different ingredients). In contrast, linearity means the whole is *equal* to the sum of the parts (e.g., the cost of the grocery bag of ingredients used to make the cake). Some phenomena exhibit both properties. The cost of buying stocks *equates* to the total cost of all of them added together (linear). But the variation (*difference*) in those stock prices is often chaotic (nonlinear) (Alvira, 2014b).

Liang (2017) further distinguished linearity and nonlinearity by the proportionate relationship between cause and effect. With linearity, a small cause always leads to a small effect, for example. Such actions are predictable, objective and orderly. In contrast, nonlinear systems have nonproportionate relationships between cause and effect. A small, leveraged action can lead to systemwide change – to a very large effect. This chaotic, disorderly and unpredictable result is amplified by the emotional and subjective human thinking dimension of systems behaviour (Liang, 2017; Senge, 2006).

Complex Adaptive Systems

Complex adaptive systems (CAS), like the stock market, an ant hill or a family unit, defy prediction because they are self-organizing (i.e., able to spontaneously adapt without the need for external control). They "are neither stable nor unstable [but] operate at the boundary between the two zones. [They are said to exist] on the edge of chaos" (Dann & Barclay, 2006, p. 22), which is order emerging just not predictably.

The edge of chaos can be a space or a boundary. As a space, it can be both physical (e.g., moving into a tornado-hit region) and mental wherein people are at their highest level of adaptability and innovation. As a boundary, the edge of chaos refers to the edge of things where high turbulence exists with great potential; it is the edge of emergence (Liang, 2017) where things can cross thresholds and transcend (i.e., climb up and over to a new space).

In CAS, order and uncertainty can coexist, like in a stock market. There are "continuous changes involving high finite dimensionality" (Liang, 2017, p. 562), meaning many variables are constantly changing moving toward some sort of temporary equilibrium. This dynamic is exacerbated by the existence of (a) the *known* (what they know), (b) the *known unknowns* (what they know they do not know but can learn) and (c) the *unknown unknowns* (unexpected and unforeseeable conditions that can appear suddenly creating crippling surprise and total uncertainty and risk). Each person addressing a problem comes to the table with a different take on these three aspects of nonlinear thinking (Appelo, 2010; Liang, 2017) further exacerbating complexity thinking.

Complexity Thinking

Those involved in complexity thinking "work the system, not the people" (Appelo, 2010, Slide 61). They appreciate that with a complicated problem, they can simplify the system to make it understandable. With a complex problem, however, they cannot linearize the system to make it predictable, because complexity is nonlinear. They further realize that self-organization is a process wherein structures or patterns appear without a central authority creating them or an external entity imposing them (Appelo, 2010; Goldstein, 2016, 2017; Liang, 2017). They arise from the interactions and relations among the people within the system.

Linked with this is the process of *emergence* (i.e., gradually coming into existence). Some things that emerge (e.g., knowledge, behaviour, properties, new patterns) cannot be traced back to any*one* person. But, if everyone involved in its creation owns the emergent artifact (i.e., embodies it), it is easier to make collective decisions using this new cross-fertilized entity (Appelo, 2010; Liang, 2017). When knowledge is cross fertilized, the multiparty interaction and interchange have lead to a mutually beneficial outcome (McGregor, 2018a). Coincidently, these are the four characteristics of transdisciplinary epistemology (knowledge) (McGregor, 2018a; Nicolescu, 2005).

Relative to the TD *axiom of identity* and the role it plays in the creation of the new **T** state (see Table 1), as people work together to share disparate ideas and insights, something new begins to emerge, something that, if nurtured, can grow into its own identity rather than merely be a part of the whole. This new identity has its own characteristics that set it apart from the original elements from which it emerged (Sanderson, 2018). Nicolescu (2014) called this transdisciplinary knowledge that is now ready to be used by many actors to address the problem in situ.

Complexity thinkers also appreciate that the triadic construct *known–known unknowns–unknown unknowns* heightens the link between uncertainty and knowledge creation to address complex wicked problems. When nonlinearity is present in complex thinking scenarios, the dynamic can become chaotic (unpredictable) (Liang, 2017) requiring a unique logic to reason through it – the logic of complexity (Nicolescu, 2005; Serrat, 2017).

Logic Defined

Complex problems can best be addressed by using "strategic reasoning, insightfulness, perseverance, creativity, and craftsmanship" (Costa, 2020, para. 1). Of these five approaches, this paper focuses on *reasoning*, specifically *logic* and the role it plays in creating TD knowledge to address complex, wicked problems. Logic is Greek *logike tekhne*, "the art of reasoning" (Harper, 2020). Logic refers to "the *way* or *mode* of thinking or reasoning that informs [a] thought strategy" (Preiser, 2012, p. 20). Nicolescu (2005, p. 17) described logic as "our habits of the mind" that influence reasoning and inference. A habit is

a settled, well-established and regular tendency to do something in a particular way (Anderson, 2014); in this case, to think. Nineteenth century American educator Horace Mann said that a "habit is a cable; we weave a thread of it each day, and at last we cannot break it" (as cited in Costa, 2020, para. 1).

Reasoning

Applying logic depends on reason, which is Latin *reri*, "consider" (Harper, 2020). Reason is the "power of the intellect to comprehend, reflect, abstract, and draw conclusions" (Rohmann, 1999, p. 337). An un*reason*able person is illogical and irrational, meaning their unconsidered actions are not based on reason or logic. Reasoning refers to using the power of the mind to consider, understand and think about things and then form thoughts, opinions and judgements (Harper, 2020; Rohmann, 1999).

Reasoning is a type of thought, and logic is an attempt to describe the rules or norms by which this thinking happens. Logic happens inside a system following a set of rules, and reasoning happens outside the system by working the problem (forward and backward), skipping logical steps, changing the rules, or diagramming things (Hofstader, 1979). Walton (1990, p. 403) further distinguished between "reasoning in logic" (step-by-step process moving from assumptions to conclusions following rules or warrants) and "reasoning in psychology" (actual thought processes involved in exercising the mind). This paper leans toward the latter – mental processes involved in working the problem.

Inferences

In addition to reasoning, logic requires people to draw inferences (i.e., conclusions based on reasoning and evidence) (Gensler, 2017; Walton, 1990). Infer is Latin*inferre*, "to carry forward, bring about" (Harper, 2020). Inferences are evidence-based guesses. People read or hear something and then draw conclusions based on what was *not* said. Instead of depending on explicit statements expressed in words, people draw conclusions based on their reasoning using available evidence. They cannot assume that people express everything needed for another person to construct their intended *meaning.* Thus, when applying reason to consider another's comments, people often have to infer (extrapolate) what was meant. Any inference that does not arise from available evidence is mere conjecture or speculation (Flemming, 2013).

Fallacies and Paradoxes

Logic also involves fallacies and paradoxes (Cantini & Bruni, 2017). Fallacies are flaws in reasoning that deceive or mislead people. Also called errors in logic or fallacious reasoning, an example of a fallacy is distracting a person from the claim being made by introducing another topic that is easier to argue – called a red herring. Another example is making someone else's argument look weaker and easier to dismiss than your own claim – called a strawman (McGregor, 2018b, Chapter 17).

Paradoxes contrast two normally unassociated ideas to create a provocative idea (e.g., 'Less is more' and 'It is kind to be cruel'). They serve "to arrest attention and provoke fresh thought" (Editors of Encyclopedia Britannica, 2020, para. 1). A paradox combines contradictory elements to the point of being seemingly absurd and contrary to accepted opinion ("Paradox," 2020). "The point of a paradox is to point out a truth, even if the statements contradict each other" ("Examples of paradox," 2000).

Logical Thinkers and Sound Reasoning

Logical thinkers have several habits of mind that distinguish them from illogical thinkers. Foremost, they try to arrive at the truth of things: both what is real (ontological truth) and statements about it (logical truth). They get their facts straight and make sure their articulated ideas match the facts. They constantly test their ideas to make sure what they are saying reflects what they are seeing and thinking about. They are attentive to and aware of the whole situation. When making a rhetorical and logical claim, they communicate using clear and understandable language geared to their audience (McInerny, 2005).

Logical thinkers capable of engaging with complex problems are aware of their own thought processes (metacognition) and have a questioning attitude, always looking for problems to solve. They think flexibly (i.e., look at things in different ways), which helps them to generate novel ideas and strategies. With an adventuresome spirit, they take intellectual risks and are prepared to experience awe and wonder as they seek truth. They strive for accuracy, are thoughtful and deliberative (i.e., think before they act) and are willing to admit when they do not know something (Costa & Kallick, 2000). Their application of logic and reasoning leads to convincing, valid arguments (i.e., a set of reasons given in support of something) (Walton, 1990).

Traditional Laws of Thought (Exclusive Logic)

Classical linear logic is predicated on three traditional laws of thought: the (a) axiom of identity, (b) axiom of contradiction and (c) axiom of the excluded middle (third) or exclusive logic (Hamilton, 1859; Russell, 1912) (see Table 1). Readers will recognize these laws by their familiar triadic structure: A, non-A, and the absence of a third state **T** that is simultaneously A and non-A. This logic is predicated on linearity (previously discussed) and duality. Dualism reflects *either/or thinking*. There is no room for contradiction – no gray area. Something cannot be both A and non-A at the same time (e.g., cannot simultaneously be true and false). The traditional laws of thought have held sway for more than 2000 years, since Plato and Aristotle's time (Nicolescu, 2014).

Table 1

Comparison of Traditional Laws of Thought (Linear) and Complexity (Nonlinear) Logic

Classical Linear Logic (Simplicity and Duality) ***Logic of the Excluded Middle*** **Reinforces Tension between A and Non-A**	***Contemporary Nonlin (Complexity and Non Logic of the Include*** **Frees Tension between A**
Axiom of Identity: A is A. • Everything is itself. • Whatever is, is.	*Axiom of Identity*: A is A. • Everything is itself. • Whatever is, is.
Axiom of Contradiction: A is not non-A. • No thing having a given quality also has the negative of that quality. • Nothing can both be and not be (e.g., be true and false at the same time).	*Axiom of Contradiction*: A is not no • No thing having a given negative of that quality. • Nothing can both be and and false at the same time
Axiom of the Excluded Middle (Third): There exists no **t**hird term **T** that is at the same time A and non-A. This **T** cannot exist in contradiction. No reconciling third possibility is logically foreseeable. • Everything must <u>either</u> be <u>or</u> not be – dualistic. • Everything <u>either</u> has a given quality <u>or</u> has the negative of that quality (e.g., it is either this or the other but not both).	*Axiom of the Included Middle (Thir* **t**hird term **T** that is at the same time **T** can coexist in contradiction, beca actualized, non-A is potentialized w disappearing entirely - a reconcilabl foreseeable. • Things can remain distinc separate (e.g., mind and b nondualistic. • Things can (a) <u>both</u> be thi one or (b) <u>both</u> be <u>neither</u> other one.

Exclude is Latin *excludere*, "to shut, keep out, hinder" (Harper, 2020). People applying exclusive logic (i.e., the logic of the *excluded* third) would reason that there is no possibility for anything to be true and false at the same time. Suggesting such a thing is illogical. For example, the mind is one thing, and the body is another. Based on this premise, Western medicine has evolved based on empirical science and controlled

experiments (e.g., the body) with no room for intuitive, spiritual or transcendental ways of knowing (e.g., the mind). Nicolescu (2014) framed this as the huge divide between technoscience and spirituality.

Excluded logic assumes that people can say something is true or false, *but* they cannot say it is neither true nor false or it is both true and false. They are denied access to this conclusion, because ambiguity cannot be tolerated (i.e., not clear, undecided). Things *either* are *or* they are not. There is no middle ground, which is why this is called the logic of the excluded *middle*. This logic assumes that knowledge cannot evolve if there is ambiguity (Nicolescu, 2014). The damage caused when using exclusive logic to address complex wicked problems is that it rules out too many things that might be fundamental to addressing the problem. And, it negates the possibility of contradictions and antagonistic ideas coexisting with the potential to generate something new by resolving the tension between them (Nicolescu, 2002) (to be discussed).

Transdisciplinary Logics

Transdisciplinarity was conceived partially to stave off the inadequacy of classical linear logic to address complex wicked problems. In particular, Nicolescu (1985, 2002, 2014) respected but took issue with linear logic's triadic structure: A, non-A and the excluded middle **T** (see Table 1). Indeed, "very few would try to maintain that [traditional logic] is adequate as a basis for understanding … everyday reasoning" (Smith, 2017, para. 5). "Even Aristotle considered the law of the excluded middle somewhat shaky" (Rohmann, 1999,p. 236). "Reason is contradictory in its own nature" (Nicolescu, 2014, p. 132).

Nicolescu (2002, 2014) is a theoretical quantum physicist who is especially concerned with the global trend of relying on exclusive logic to address the problems facing humanity. He challenged the traditional tertiary approach and formulated a new one (see Table 1) along with a totally new methodology for creating knowledge that bridges disciplines and the life world (i.e., governments, businesses and civil society). As with conventional methodologies for producing or creating new knowledge (i.e., empirical, interpretive and critical) (McGregor, 2018a,b), Nicolescu's (2002) methodology is based on three philosophical axioms: ontology, epistemology and logic; axiology (values) is also an axiom but not so for Nicolescu's approach. Axioms are self-evidently true principles – no need to explain, question or demonstrate; their truth is obvious. If someone says something is so, you can take their word for it (McGregor, 2018b).

In more detail, first, transdisciplinary reality (*ontology*) exists along many levels (TD-Subject [perspectives and consciousness] and TD-Object [facts, evidence, statistics]). Respectively, examples include individual psychology and philosophy, history, and political ideology (TD-Subject) and economics, technology, and environment (TD-Object). Interaction among these seemingly contradictory realities is mediated by the unifying force of the Hidden Third (such as art, drama, music, culture, spirituality). People meet in a mental zone of nonresistance to each others' ideas to create new knowledge. Second, transdisciplinary knowledge (*epistemology*) is complex, emergent, embodied and cross fertilized. These two axioms are described elsewhere with deeper and broader coverage (McGregor, 2011, 2018a; Nicolescu, 2002) with the remainder of this paper focused on the third axiom – *logic* (see Figure 1).

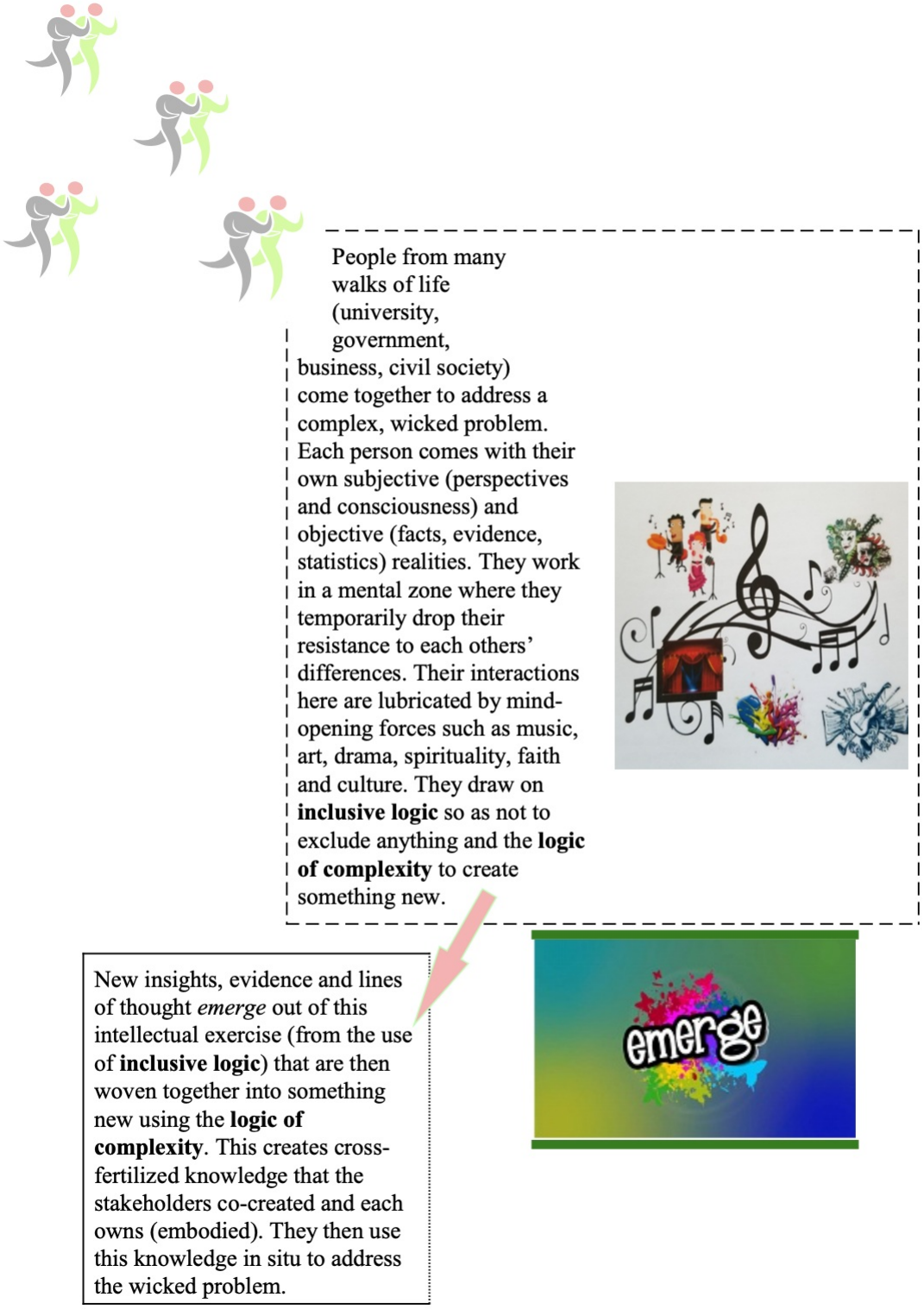

Figure I – Using Inclusive Logic and the Logic of Complexity When Creating Transdisciplinary Knowledge

With the advent of the new sciences about 100 years ago (i.e., quantum physics, chaos theory, and complexity theory), challenges to linear logic appeared. A key champion of this effort, Nicolescu (1985, 2002, 2005) formulated two logics: (a) the logic of the *included* middle (inclusive logic) and (b) the logic of complexity. The former deals with reconciling contradictory and antagonist ideas so new facts, thoughts and insights can emerge, and the latter helps people to weave these new disparate strands of thinking into a complex new whole. In short, inclusive means including integral elements whose absence would be notable, and complex means embraced, braided and intertwined (McGregor, 2018a).

Inclusive Logic

Nicolescu (2002, 2014), a Romanian quantum physicist, drew heavily on Stéphane Lupasco's philosophical work to develop inclusive logic. Lupasco was a Romanian philosopher who developed non-Aristotelian logic. Convinced that the traditional laws of thought were "no longer valid in the quantum world" (Nicolescu, 2014, p. 126), Lupasco formulated a third axiom – the *included* third to replace linear logic's axiom of the *excluded* third (see Table 1); there *can* be a *middle* ground from which complex new knowledge emerges.

Not discussed in this paper, Brenner (2011) called Nicolescu's (2002) logic of the included middle "Logic in Reality" (p. 3). Brenner hypothesized that the dualistic characteristics of reality "can be formalized as a structural logic principle of dynamic opposition, an antagonistic duality" (2011, p. 3). He formulated his own version of Table 1 with three modified axioms: (a) *non*-identity, (b) *conditional* contradiction and (c) the logic of the included *emergent* middle.

This section teases out Nicolescu's (2002) formulation of inclusive logic. Inclusive is Latin *inclus*, "to enclose, insert" (Harper, 2020). In short, at the same time contradictions exist (A and non-A), a third **T** state *can* simultaneously exist, meaning the contradictions are brought together and can coexist but do not merge, do not exclude each other and never disappear (Desbois, 2012) (e.g., the mind and the body). This is a prime example of nondualistic thinking (see Table 1).

Desbois (2012) further suggested that while addressing TD problems, any opposing ideas "cancel each other out" (p. 95) thereby enabling the new **T** state to emerge. This means "both opposing ideas are equal to each other in force or importance but are opposite to each other and thus have no effect" ("Cancel each other," 2020). Any potential effect they might have had on addressing the problem is reduced or cancelled; neither gains an advantage or becomes privileged. But – and this is important – the mere fact they were brought together is why something new was created that would not have happened otherwise. Their juxtaposition in the new **T** state was made possible through inclusive thinking.

Using inclusive logic, people can reconcile disparate mind sets and make room for anything that helps to address the problem even if it is originally perceived as not compatible or antagonistic, prompting tension and resistance. Also, the struggle between opposites and contradictions does not result in the two aspects being separated; they can remain distinct without being separate (like the mind and the body) (Desbois, 2012). Actually, they are inseparable, because the existence of one means its opposite must also exist – one cannot exist without the other, which is very different from it is *either* one *or* the other (dualism) (Nicolescu, 2014).

Nicolescu (2014) acknowledged the tension that emerges when reconciling contradictions, claiming that the "*emergent antagonism is thus a view of the world's unity*… Everything is linked to the world … Everything is a constituent part of the universe" (p. 131). People and things are nonseparable from the world. The logic of the included middle accommodates this quantum principle: universal interdependence. Within the temporary **T** state, a contradiction is resolved at a higher level of complexity than when problem solving started, which is clear evidence of a temporary resolution of tension through the use of inclusive logic (Nicolescu, 2014).

As an example, a corporate engineer has been tasked with building a dam that will unfortunately destroy Indigenous lands. Elders are adamant that this does not happen. The government sympathizes with the Indigenous people but remains in favour of the dam, because it generates electrical power for the country. Through contentious and tense dialogue shaped by all of the stakeholders' subjective and objective stances (realities), and by using inclusive logic (i.e., not leaving anything out while remaining open to new ideas), they can reach a 'meeting of the minds' so that the complexity of the situation can be respected and accommodated.

Cyber-space-time. Time and space are another key aspect of the logic of the included middle (leading to the third **T** state) (Nicolescu, 2002, 2014). Classical physics respects the space-time continuum (i.e., the continuity of time). This continuum has four dimensions: one dimension of time and three dimensions of space. Time and space are intimately linked and thought to be smooth and continuous (Nicolescu, 2014); that is, "one cannot pass from one point of space and of time without passing through all intermediate points" (McGregor, 2011, p. 2) (i.e., no reversals, exceptions or skipped stages). This principle means that people would ineffectively follow a series of steps or formulae to address a complex wicked problem.

Conversely, quantum science assumes that space-time is not always continuous (Nicolescu, 2014). Discontinuous means that "between two points there is nothing [except for] a gap of potentialities" (McGregor, 2011, p. 2); in other words, a quantum vacuum that is at its lowest level of energy but not an empty void. When addressing a wicked problem, people would remain open to possibilities and emergence thereby eschewing the principle of continuity (linearity). For Nicolescu, discontinuity is actually a "place void of logical reason and reflects the dark light of the unknown that paradoxically cooperates with the known by injecting information into the Kosmos" (personal communication, January 10, 2011).

Respecting discontinuity (i.e., the presence of gaps and interruptions), instead of continuous space-time, transdisciplinarity engages with *discontinuous cyber-space-time* (CST) (Nicolescu, 2002, 2014). *Cyber* is a word-forming element from cybernetics, which is the theory and study of communication and control (Harper, 2020). Cyberspace is the notional (in the mind only) environment in which communication over computer networks occurs (Anderson, 2014; Mihalache, 2002). A contemporary example is the Internet, also called cyberspace.

First coined in 1982, adding the word *cyber* to space-time was a way to capture the phenomenon of a previously nonexisting space that emerges in the process of communication and development (Mihalache, 2002). Put simply, as people engage, a new space is born, which he called cyber-space-time. Nicolescu (2002) proposed that inclusive logic is at work in this space, which is "the transcultural, transnational and transpolitical … space of human choice" (p. 82).

Just like the classical space-time continuum is associated with the speed of light, so too is CST. Nicolescu (2002) argued that bringing the human into CST "alerts us to a new level of perception (basically that of the encounter with the 'light barrier'), which reveals a world that breaks radically with the macrophysical world in which we pass our life. This 'new world' is not ruled by classical logic" (p. 79). Instead, moving around CST requires people to use the logic of the included middle to navigate interactions with each other (subjective) and the objective world much like they use nonlinear logic (e.g., Boolean searches using *and/or*) to navigate the internet (Nicolescu, 2002).

Nicolescu (2002) considered cyber-space-time a connecting principle that bridges mind (perceptions and consciousness) and matter (facts, evidence, statistics) to make levels of perception more evident as people cross realities and communicate. The **T** state, resulting from the actualization of A leading to the potentialization of non-A, deals with "time and space linked by a relationship of contradiction" (Nicolescu, 2014, p. 132). This relationship has to be mediated using both the logic of the included middle and complexity logic.

Quantum paradox. Logic involves paradoxes (Cantini & Bruni, 2017). Nicolescu (2014) argued that the logic of the included middle helps people to understand the quantum paradoxes generated by quantum mechanics. Especially, each particle (A and B) is in an uncertain state; it is in a superposition of possible states (i.e., the quantum ability to be in multiple states at the same time *until* measured) (Nicolescu, 2014; Rouse, 2020). When A is measured or observed, its state becomes certain. Moreover, because these particles are quantumly entangled, when A is measured, B knows what its state is supposed to be (Jones, 2019). This phenomenon (i.e., particle spin) is called a quantum paradox, because "it seemingly involves communication between two particles at speeds greater than the speed of light, which is in direct conflict with Einstein's theory of relativity" (Jones, 2019, para. 2).

This invisible phenomenon of changes in quantum states cannot be observed with the human eye, but the consequences can be measured (Rouse, 2020) – much like the process of addressing complex, wicked problems cannot be *seen* but the results can. Things are in an uncertain state, until they are not. Until they change, many possibilities exist. Once they change, something different exists – because actualized A helped potentialized non-A to emerge (Brenner, 2011). This interpretation of the quantum paradox has informed transdisciplinarity and complexity where paradoxes "are widespread in contrast with the rigid logic of binary oppositions" (Marzocca, 2014, para. 7; see Nicolescu, 2014).

Indeed, complexity thinkers themselves manifest several paradoxes. They are smart yet naive, disciplined yet playful, rooted in their reality while open to imagination, and open and sensitive although this exposes them to loss and stress (Csikszentmihayli, 1996). Comfortable in these paradoxes, they can "cross the boundaries of closed systems, explore non-empty spaces between disciplines and often assess the inclusion of the excluded middle in a binary logic of opposition" (Marzocca, 2014, para. 9). With this assessment unfolding in cyber-space-time, they can *choose* to apply the logic of the included middle to deal with complexity.

Complexity Logic

If the role of classical logic is to remove or prevent contradictions in thinking (Landauer & Rowlands, 2001), then the logic of complexity acknowledges and accommodates contradictions (see Table 1). "Complexity has its own logic" (Desbois, 2012, p. 94). The logic of complexity lets people cross and connect different ways of knowing and perceiving in creative and coherent ways thereby "enabling a new kind of simplicity" (Nicolescu, 2000, para. 27). Respectively, inclusive logic and complexity logic temporarily reconcile contradictions inherent in multiple perspectives and information and allow for different ways of knowing to be interwoven to form TD knowledge (Nicolescu, 2002, 2014) (see Figure 1).

Generalized complexity. Nicolescu drew heavily on Edgar Morin's (1974, 2008) work on complexity thinking to develop his approach to the logic of complexity. Nicolescu (2005) believed that although Morin's approach does not deal with levels of reality or the included middle, it "is compatible with these notions" (p. 22). Morin (1984) cautioned that "if we do not want to seriously mutilate reality [we have to become comfortable with] the unthinkable, inconceivable, and unsayable. [This way] the world is totally thinkable" (p. 67). "Morin recommends the adoption of open thinking, accepting negotiation with the unknown, and a knowledge that is aware of the ignorance that it brings" (Nicolescu, 2014, p. 134).

Useful here is Morin's (2005) notion of *generalized complexity*. Quantum science respects the principle of universal interdependence (Nicolescu, 2005, 2014) thereby enabling Morin to equate generalized complexity with "the generalized interdependence of everything and everyone" (2005, p. 21). This means that when dealing with complexity, people cannot create new knowledge *unless* they "try to comprehend the *relations* [emphasis added] between the whole and the parts" (Morin, 2005, p. 6) instead of the characteristics of the parts and the whole. These relations are compelling and alive (always in formation) as well as intertwined.

Morin (2005) actually wondered whether the force that emerges among these relations is "a hidden force of nature, an intrinsic virtue" of complexity work (p. 8). This query makes sense in that complexity thinking "takes place in the force field where the tension between differences is upheld, brought together and kept apart at the same time [thereby giving] the 'logic of complexity' a paradoxical character" (Preiser, 2012, p. 201). Morin (1974) believed that complexity thinking entails thinking about opposites at the same time (i.e., holding both in your mind while you think) instead of just describing each one and setting it aside assuming they cannot occupy the mind at the same time because they push against each other.

Complexity in cyber-space-time. Because levels of Reality interpenetrate, logic of complexity is needed to deal with the inherent tension (Cillier & Nicolescu, 2012). Actually, complexity is conceived differently in cyber-space-time, because space is no longer seen as smooth (as in the space-time continuum). Instead, space is described as "*quantum foam* to describe the turbulence [and tension]" (Nicolescu, 2014, p. 67). Instead of linearly moving through "*distance between points*" (continuity) (Nicolescu, 2014, p. 68), people would move through a complex and turbulent space comprising a mass of small bubbles. Cyber-space-time consists of many small, ever-changing regions. Therein, space and time are not definite but fluctuate in a foam-like manner (Wilczek, 2010). When addressing complex problems, these small bubbles could represent the many diverse mindsets vying for a voice. Such complex interactions merit a logic of complexity when linearity and predictability have been removed.

Types of complexity. Because "complexity is changing in its nature," it cannot be reduced to simplicity (Nicolescu, 2014, p. 107). By association, "the logic of complexity is not a call for rejecting logic, but a call to expand it and open it up to the heterogeneity of complexity" (Preiser, 2012, p. 201). Respecting this dynamic and diversity, Nicolescu (2005) elaborated on three types of complexity. *Horizontal complexity* concerns a single level of Reality and the connections of complex phenomena within that Reality (e.g., economics). *Transversal complexity* focuses on crossing different aspects of one level of Reality (e.g., different types of economics: classical, ecological, feminist, behavioural). *Vertical complexity* refers to crossing several levels of Reality (e.g., economics, social, and historical). As people engage with different realities and types of complexities, they gain glimpses within that "generate reciprocal enrichment that may facilitate the understanding of complexity" (Max-Neef, 2005, p. 15).

Simplexity/complexus. From another perspective, Nicolescu (2010) said that "one level of Reality is the *simplexus* of the *complexus* present in Trans-reality" (p. 8). *Simplexus* means 'with one fold' and complexus means intertwined (Gélalian, 2018). By complexus, Nicolescu (2010) meant the unification of different types of complexity, what he called *transcomplexity* but never defined. Luna and Alfonzo (2016) later clarified that with transcomplexity, people are able to break away from dominant ontological visions (e.g., traditional laws of thought) that can restrict their knowledge awareness. Using the logic of complexity enables people to (a) have their truths, knowledge and models of the world while (b) challenging them to know the limits thereof and reevaluate them each time they are used and reinvent them if necessary (Preiser, 2012).

Nicolescu (2014) further recognized the misleading dualism of simplicity/complexity, arguing instead that they do not oppose each other but are interdependent. To better explain, he employed the term *simplexity*, which refers to the process of striving toward simple ends by way of complex means (simplexCT, 2013). "The new simplicity arises as an outcome from the process of many interdependent people working across many complex levels of Reality, achieved via simplexity" (McGregor, 2018a, p. 191).

Pragmatic Connections

In summary, Nicolescu (1985, 2002) contributed two new logics to augment traditional laws of thought, which are valuable but not privileged. He formulated (a) the *logic of the included middle* to make room for many

voices and points of view, the better to come up with new ideas for addressing wicked problems. And he formulated (b) the *logic of complexity* so that people have a way to weave these new emergent lines of thought together into innovative, agreed-to schema. As people pragmatically try to apply those logics when addressing complex wicked problems, they can turn to more conventional strategies used by people who are inclined to think about complexity.

In more detail, complex problems manifest when people experience dilemmas, a situation when they have to make a difficult choice between alternatives when the decision may bring negative or undesirable consequences (Costa, 2020). Inclusive logic and the logic of complexity are designed to help people to negotiate their way through a dilemma where many vying voices are present. These logics create disruption leading to interruption (stopping a process) and the opening of a liminal space where threshold crossing is possible (Preiser, 2012). Wicked problems exist when thresholds have been crossed (Head, 2008). Liminal is Latin *limen*, "threshold" – a barely perceptible space that is neither here nor there. When people enter this space, they stand on a threshold where something can cease to exist or come into existence (Turner, 1974).

Crossing this threshold opens the opportunity for the unity of knowledge (Nicolescu, 2002). But "the problem of complexity is not one of completeness, but rather of incompleteness of knowledge" (Morin, 1984, p. 63). Complex thought accommodates what would normally be excluded or discarded when engaging with linear thinking, which leads to incomplete and short-circuited coverage of a problem (Morin, 1984). Thus, "the manifest goal of complexity is to become aware of the links that are broken by separations" (Morin, 1984, p. 63) between disciplines, categories, sectors and different types of knowledge. Transdisciplinary logics better ensure the creation of 'more complete' knowledge to address the complexity.

Transdisciplinary Mind Habits

It helps to appreciate that Nicolescu (2005) adopted a theoretical and philosophical approach to deal with complex problems, while other scholars have taken a more pragmatic approach. To illustrate, seven habits of a *transdisciplinary mind* have been identified. These are cognitive skills that individuals habitually use when they are *already* predisposed to think across a range of domains and inclined to integrate different solutions, viewpoints and perspectives (Mishra & Koehler, 2006; Mishra, Koehler, & Henriksen, 2011).

These transdisciplinary thinking habits can also be learned. They include perceiving (awareness and consciousness), recognizing patterns, abstracting (extracting separate elements and explaining them), embodied thinking (kinesthetic sensing and empathic positioning), modelling (includes dimensional thinking – space and time), playing deeply and intellectually with ideas, and synthesizing (making complex connections) (Mishra & Koehler, 2006; Mishra et al., 2011).

Transdisciplinary Relational Logic

Desbois (2012) offered an especially useful contribution by respecting the reality that transdisciplinary work is grounded in relationships, a sentiment shared by Morin (2005), a renowned complexity-thinking scholar. When referencing Nicolescu's logic of the included middle, Desbois (2012, p. 94) coined the term "the logic of conciliation." Choosing the verb *conciliate* indicates his appreciation for the concurrent messiness *and* richness of addressing problems amongst disparate but committed people. He tendered a collection of ideas pursuant to understanding the nature of relationships among people working on complex problems and managing attendant risks emergent from collaborative work.

Pithy examples from Desbois' (2012) work include (a) act like a thinking person and think like an acting person, (b) gaps identified are precious resources, (c) create opportunities by using the potential of contexts at the right moment (leverage), (d) stability is an illusion and impermanence is the essence of continuity and (e) every in-process answer becomes a knowledge springboard. People are urged to (f) convert doubt into a resource, (g) seek others' point of view and then bring these together to create new logical links and (h) accept that change is an identity-related process tied to free will. He assumed that complexity cannot be dealt with unless people learn to *think* together using logic other than exclusive logic.

Learning Organization Logic

Senge (2006, another complexity scholar, conceptualized the learning organization. These complex adaptive systems are self-organizing, much like working in the zone of nonresistance to create new transdisciplinary knowledge via simplexity. They take on a life of their own that is not dependent on external steerage or leadership. The latter emerge from within. Like Nicolescu (2014), Senge (2006) believed that "*When we try to pick out anything by itself we find it hitched to everything else in the Universe*" (John Muir as cited in Gifford, 2006).

And like Morin (2005), Senge (2006) was concerned with interactions as a whole rather than people as a whole. He conceptualized that learning organizations nurture new and expansive patterns of thinking, set free collective aspirations, and learn to see the new, emergent whole, together. They approach the learning enterprise (i.e., creating new knowledge) with complexity thinking so that people can envision connections that have not yet materialized.

In this learning environment (what Nicolescu, 2002, called levels of Reality interfacing in the zone of nonresistance), Senge (2006) claimed that people come with their own mental model of the world (see also Preiser, 2012); that is, their internal pictures, assumptions, perceptions, meanings and stories. Using what Nicolescu (2002) called inclusive logic, members of the learning environment come up with a shared vision, an internalized picture of a desirable future that pulls them forward in the same direction. Inspired by this vision, they think together in dialogue enabling them to receive insights that were not available to individuals alone. Ideally, people will tap into their ability to handle creative tensions or be open to learning how to do this so group learning can continue (Senge, 2006; see Preiser, 2012).

Similar to Appelo's (2010) notion of working the system not the people, Senge (2006) felt that people should manage the commons not the people. This involves gaining insights into the system's behaviour (e.g., the zone of nonresistance) so any limiting factors can be identified and inhibited so collective learning and knowledge generation can proceed. To that end, in a process rife with contradictions that have to be held in thought, he advised against diverting resources to one of two deserving things, opting instead to ensure both can flourish until something new emerges (i.e., confront dualism, respect nondualism). Instead of pushing hard for success, remove factors that are inhibiting success. This way, new things can emerge with less tension involved. Senge (2006) especially lauded the principle of leverage wherein the best results come from small, well-focused actions instead of large-scale efforts, especially if they are at the right place at the right time. The latter is more feasible if people are paying attention to the commons and dynamics.

Conclusion

This paper teased out Basarab Nicolescu's transdisciplinary logic axiom – the logic of the included middle and the logic of complexity. His philosophical and theoretical approach was briefly augmented with some on-the-ground pragmatic ideas about working with complexity. Together, they provide deeper insights into the logical underpinnings of transdisciplinarity that challenge two millennia of classical linear logic. Inclusive and complexity logics accommodate the necessity of not excluding anything that might be integral to the solution and the attendant ability to weave emergent ideas into something new. Addressing complex wicked problems depends on new laws of thought – transdisciplinary logic and habits of mind.

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