

Complexity leadership in transdisciplinary (TD) learning environments: a knowledge feedback loop

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ABSTRACT. The conception that leadership is the activity of individual actors is challenged by a more dynamic approach that regards leadership as processes that influence organizations. This influence is a catalyst in the creation of new knowledge especially in environments where innovation is a key characteristic. The purpose of this paper is to suggest a model grounded in the complex adaptive systems (CAS) within transdisciplinary (TD) settings and to highlight the dynamic mechanisms that allow for emergent new knowledge informed by complexity leadership theory (CLT). The theoretical model provided presumes i) a context of TD; ii) leadership as an agentic process; iii) entanglement as a fundamental leadership function in CAS; iv) multi-level interventions; and v) a proposed knowledge feedback loop that serves as a driver for continual renewal to the adaptive system.

KEYWORDS: Complexity, Entanglement, Intervention, Leadership, Transdisciplinary

"We must broaden our perspectives to include a more distributed concept of human interactions, we must add specificity to our models of social interactions, and we must continue to relate our theoretical and simulated models to the practices of human interaction" (Schwandt, Szabla, 2007, p. 59).

Since the height of the industrial age, models of leadership have been focused on the classification of individual leaders acting as primary agents of change and motivation within organizations. From "great man" theories and trait approaches to path-goal and leader-member exchange theories to even more modern approaches like transformational and distributed leadership models, the individual remains the dominant actor in social networks. "The component most common to nearly all classifications is that leadership is an influence process that

assists groups of individuals toward goal attainment” (Northouse, 2007, p.12). While this approach is continually promoted, by focusing on the individual as a *catalyst*, historical models have proven to be too constrictive in light of an emergent paradigm that encourages the value of “enabling characteristics” rather than the “determining or guiding” role of the individual ensuring organizational effectiveness (Marion, Uhl-Bien, 2001, p. 389). Where once stability, regularity, indifference, and order were the goals of good management, in a new age of knowledge, “the task that justifies the existence of all managers has to do with instability, irregularity, difference, and disorder” (Stacey, 1996, p. XX) -in other words, *dynamism*. This shift in perspective is a realignment of the question “What is leadership?” It identifies the dynamic characteristics applicable to the unique and complex needs of management in environments where systemic and dynamic relationships are central rather than the search for individualized and static descriptions of purpose. “This new age is about an economy where knowledge is a core commodity and the rapid production of knowledge and innovation is critical to organizational survival” (Uhl-Bien et al., 2007, p. 299).

This paper suggests a knowledge model grounded in complex adaptive systems (CAS) within transdisciplinary settings (TD) and highlights the dynamic mechanisms that allow for new emergent knowledge informed by complexity leadership theory (CLT). The theoretical model is built on i) a context of TD, ii) leadership as an agentic process, iii) entanglement as a fundamental leadership function in CAS, iv) multi-level intervention, and v) a proposed knowledge feedback loop that serves as a driver for continual renewal of the adaptive system. The desire is to depict a model that generates a more comprehensive mechanism that considers the “connective, dynamic, and contextual views of leadership [in light of] emergent creativit  and learning” (Uhl-Bien et al., 2007, p. 302-303).

An expanded leadership concept

This new knowledge framework is made possible through an expansion of the “locus of leadership from the isolated, role-based actions of individuals to the innovative, contextual interactions

that occur across entire social systems” which are recognizably elaborative “products of interactions among agents, rather than ‘caused’ by the specific act of individuals described as leaders” (Lichtenstein et al., 2006, p. 2-3). Dynamic interchange is made possible through leadership processes (Uhl-Bien et al., 2007) that navigate tensions between “simplicity” and “complexity”, “insulation” and “hybridity”, “consensus” and “agreement”, and “universality” and “dialogue of the local-regional-global” which are highlighted to illustrate the shift in dynamics and a need for investigation of the culture for which knowledge resides (Nicolescu, 2005b, p. 7). The instabilities that these tensions create are key elements that test leadership abilities to manage and influence knowledge creation. This dynamic tension is the driver of adaptive leadership (Lichtenstein et al., 2006) and the attractors that entice “recurrent shifts in the centralization and decentralization of decision-making, or functional specialization vs. cross-functional integration” (McKelvey, 2008, p. 243). Organizational knowledge creation is grounded in the traversing between multi-layered management models that have at their core differing assumptions about the source of knowledge (Nonaka, 1994). The transdisciplinary environments that these dynamics breed are “open, evolutionary aggregates whose components are dynamically interrelated and who are cooperatively bonded by common purpose or outlook” (Uhl-Bien et al., 2007, p. 302). The challenges embedded in managing these complex and diverse agents are related to the task of leadership intervention that strives to respond to complex environments on multiple levels, thus ensuring that tensions are used to generate new understandings rather than serve as barriers to them (Hannah, Lester, 2009).

Social conflict and intervention

Tension, or “exchange”, (Blau, 1964) in social systems serves as a measurable unit and is dynamic. It leads to an analysis of social associations and the processes that sustain these relationships, their forms, and the forces that instigate such interactions. Conflict within this interactionist definition not only informs social dynamics but also describes its underpinnings and highlights the tensions that disclose them. Social exchange serves as an indicator of

the disruptive barriers within the system that communicate the inability to transcend beyond boundaries to achieve new orders of consideration. Georg Simmel calls this the “sewing together” (Simmel, 1955) of society “by a variety of cross-cutting conflicts between its component parts” (Burrell, Morgan, 1979).

Defining the coordination necessary to achieve a “sewing together” of various social affiliations might be more a matter of understanding what type of organizations breed cooperative interdependence. Coordination has as its goal the management of the “exchanges” (Blau, 1964) and “triggers” (Buckley, 1967) which emerge from interactive social environments. Through interdependent activities, conflicts and power struggles arise between “actors” (Eldridge, Crombie, 1974; Fox, 1966a; Scott, 2001). Coordination, therefore, is driven by the function of managing these interactions or “periodic attractors” (McKelvey, 2008) which are “actor” driven. These “dependencies” are not routed in the tasks of collaboration but rather are imbedded in the motivations, incentives, and emotions surrounding *why* individuals interact with each other (Malone, Crowston, 1994). They are the indicators of the tensions embedded in social action that breed opportunities for new knowledge creation.

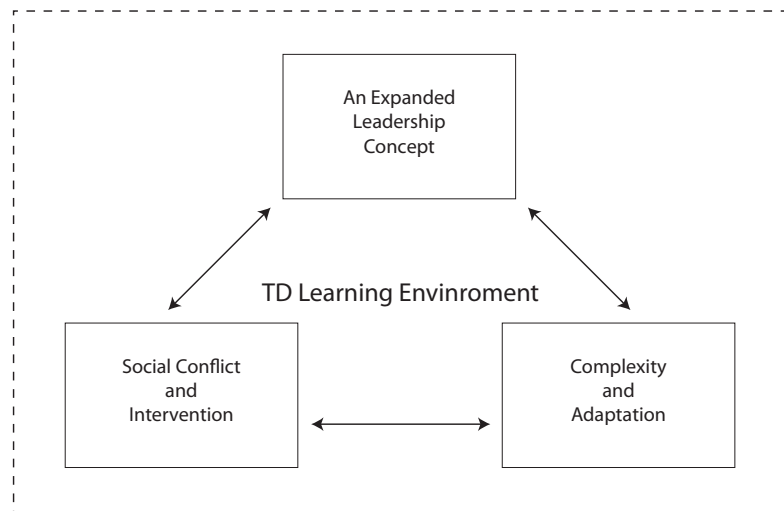
The transdisciplinarity (TD) environment

Until recently, envisioning leadership as embedded within open systems of interfacing knowledge lacked generalized theory to describe its dynamics. Much of the material about such environments has come from the patching together of various social systems theories about “crossing boundaries” (Klein, 1996), “boundary blurring” (Becher, 1990), and identifying “zones of interdependence” (Parsons, 1970) beyond mere knowing to include the interactive nature of knowledge. From these theories, notions about TD [evolving from multidisciplinary (MD) and interdisciplinarity (ID)] emerge as a new mode of governing science “directed toward solving complex issues and addressing scientific knowledge production proper, promising to circumvent the schism between scientific expertise and policy-making by... the involvement of stakeholders [that] make sure the ‘right problem’ gets addressed ‘in the right way’” (Fine, 2007; Hannah et al., 2009; Maasen, Lieven, 2006, p. 401).

Complexity within transdisciplinary (TD) learning environments

The environment that houses the aforementioned problem-solving character of TD is simultaneously complex and adaptive by nature. Its complexity is rooted in the plurality of agents that make up the influential factors affecting the whole as well as the entropy these agents provide to the overall structure. "In dealing with the sociocultural system... we need yet a new concept to express not only the *structure-maintaining feature*, but also the *structure-elaborating and changing feature of the inherently unstable system*" (Buckley, 1998, p. 85). This perspective on complexity clarifies how transdisciplinarity can be both a mechanism of social interactions as well as a nascent characteristic of a social environment challenged by its own innovation. Instability and tension are requirements for rejuvenation for the entire system. Knowledge in this light is both catalyst and product, and as we will explore later in the paper, it is dependant on leadership influences to continually feed the generative processes within the entire learning system. Social conflict and intervention, adaptation, and an expanded leadership concept that recognizes multiplicity and complexity of influence factors serves as the overarching dynamic elements of the TD learning environment. See Figure 1.

Figure 1. Conceptual framework for knowledge maintenance in TD learning environment



The relationship of these conceptual factors provides to a conversation about leadership and learning a paradigm that is capable of considering input-throughput-output as relational entities in a system. It strives to capture the characteristics of social dynamism as part of the purpose of inquiry and can suggest how through new perspectives on how systems behave learning and knowledge creation can be studied in light of the embedded tensions and emergent innovations intrinsic to most social systems.

Mechanisms of transdisciplinarity (TD)

Multidisciplinarity (MD) and interdisciplinarity (ID) as contributing mechanisms

Defining and achieving transdisciplinarity (TD) leads to consider an “economy of knowledge” (Selznick, 1948) that transcends mere MD and ID functionality. Both MD and ID (as well as TD) assume some open system capacity (Buckley, 1967; Katz, Kahn, 1966; Nicolescu, 2005b) where information exchange is essential in defining the dynamics of organizational systems. Ludwig von Bertalanffy proposed that [academies] of knowledge are at best when “complexes of elements [are] standing in interaction” with one another (von Bertalanffy, 1956, p. 26). Graybill, Dooling, Vivek and John defined MD, the lowest form of disciplinary knowledge interchange, as an economy of knowledge that involves two or more disciplines working in collaboration on a common problem (Graybil et al., 2006). In both MD and ID discourses, integration of knowledge emerges (Graybill et al., 2006; Klein, 1990). However, MD lacks the ingenuity to achieve greater understanding through its focus on multiplication of methods over hybridization of approaches (Klein, 1990, 1996, 2004).

Epistemologically speaking, ID offers new ways of working and thinking. Individual disciplinary epistemologies are diluted as hybridized styles of thought and conceptions of knowledge begin to emerge and overtake traditional methodologies and analytical enterprises generating new frames of knowing (Pirrie et al., 1998). Shifts occur between paradigms resulting in novel perspectives (Kuhn, 1970; Lawrence, Lorsch, 1967; Thompson, 1967) that lack the ability to provide innovative frameworks fostering collaborations

between disciplines and represents the cross pollination more apparent in ID “boundary crossings” (Klein, 2006b, p. 38).

Transdisciplinarity (TD)

Transdisciplinarity moves us away from a consideration of science as bound by disciplines and leads us to a more holistic schema that considers the dynamics of entire systems of actors and concepts (Klein, 1990; Tress et al., 2003). TD requires a reappraisal of integration and also a reconsideration of the systems that it brings together to achieve integrative properties making it able to respond to its environment (Lawrence, Lorsch, 1967). Kerne (2005) describes this process as a recombination-taking existing coded compositions, breaking them down into constituent elements and recombining those elements to form new ones (Kerne, 2005). Pregernig (2006) states that TD presumes an integration of disciplines providing a “synthetic reconfiguration of available knowledge regarding the social, economic, and ecological conditions” (Pregernig, 2006, p. 446). And Nicolescu, resounding Klein’s focus on crossing boundaries, highlights TD’s “coexistence between complex plurality” (Nicolescu, 2005b, p. 7).

This framework moves us away from a consideration of knowledge exchange that dwells in the category of MD and ID to a new category of TD so that research can ultimately increase a focus on interactions as the unit of inquiry. It also strives to gravitate away from the psycho-cognitive approaches which dominate learning discourses to one where social action is the driver of innovation and knowledge creation.

Social interaction approach

Interdependencies

While the aforementioned theorists have focused on economies of knowledge and the interplay between disciplinary spheres, others have highlighted the social functions embedded in MD, ID, and TD phenomena. Katz and Kahn (1966) focus on motivation as it supports energetic input output systems. They highlight that all organizations “consist of patterned activities of a number of individuals. Moreover, these patterned activities are complementary or interdependent with respect to some common output or outcome” (Katz, Kahn, 1966, p.

20). This exchanging of energy (interdependence) between actors of the system leads us to be able to identify their functions. The function of organizations is therefore 1) evidenced in the patterns of exchange that lead to a common output and 2) is sustained by the reactivation of these patterns.

Active exchanges between actors from similar knowledge traditions focuses on coordination and shows how interdependencies vary in function. This phenomenon had been a long standing preoccupation with the integrationists of the previous century who focused on conflict and its effects on “exchange” (Blau, 1964), societal “sewing together” (Simmel, 1955), non-conforming behavior (Merton, 1968), perpetual social dysfunction (Coser, 1956), disciplinary contribution to change (Gouldner, 1959, 1973), and change mechanisms and their role in innovation (Eldridge, Crombie, 1974; Fox, 1966). For James Thompson, this coordination is a matter of hierarchical order (Thompson, 1967). He recognized that interdependence occurs on three different levels representing different, more expansive relationships. Each level of coordination promotes ever more increasing complexity to the task of collaboration (Simon, 1969) and supports a reordering of the collaborative function itself (Maasen, Lieven, 2006).

Generic or pooled interdependence

Using Thompson’s hierarchy, on the lowest end of the spectrum, we see that generic or (pooled) interdependence recognizes, like MD, that coordination occurs frequently but on a primary level. This level is predominantly concerned with “standardization”. Different disciplinary actors interact by their contribution to the whole. They interact with a motivation that is limited to the goals of an overarching system, with little concern for the affect such interactions may have on their own goals or those of other systems which one might become in contact with (Ensign, 1998). Interdependence is only a matter of reference as professional collaborators, for instance, look to each other for expertise. They are interdependent by one discipline’s lack of expertise where others fill the gap. Motivation for working together are driven by apparent voids. An open system is manifested by an importation of energy from one presumably closed system (one discipline) to another by a process of “information inputting” (Katz, Kahn, 1966, p. 26) thus it should be noted that no novel output is recognizable.

Sequential interdependence

A second more direct form of coordination is that of sequential interdependence. Assuming generic interdependence, more intentionality emerges resulting in planning and coordination, Saverio Mecca (1999) has shown in construction projects that the sequencing of tasks as a means of coordinating crafts, specialists, and management teams through participative planning ultimately results in greater capabilities in dealing with environmental issues, “on site” alterations, and reliability of construction projects (Mecca, 1999). In pooled interdependence discussed above, the motivation is driven by a lack of information. Here, in sequential interdependence, motivation is driven by a desire to contribute to the “throughput” (Katz, Kahn, 1966, p. 23-24) of the system. Again, novel outputs are limited in generic interdependent relationships.

Reciprocal interdependence

The last form of interdependent relationships (and the form most influential in achieving a social TD environment) is reciprocal interdependence. Here outputs of parts of systems become inputs of others. The different parts of the organization are linked by the relationship of “homeostasis” (Katz, Kahn, 1966, p. 26-29) that drives both the need to remain continually invested in the goals of the system (sequential interdependence) as well as remaining intent on the goals of the individual or sub-group (pooled interdependence). This interdependent relationship is akin to what Klein has suggested about TD, at least on the surface level, in that engaging in collaborations is a systemic and individual enterprise. It moves us from a sole consideration of our own science beyond the boundaries of our own discipline to a more holistic model that considers the whole system and its requirements (Klein, 1990, 1998).

Reciprocal interdependence becomes therefore the hallmark of CAS that rely on the interplay of knowledge (Thompson, 1967; Uhl-Bien et al., 2007). Here, outputs of parts of systems become inputs of others. This notion will become critical to a knowledge feedback loop that sustains TD to be discussed later. Figure 2 describes the various types of interdependencies and their functions.

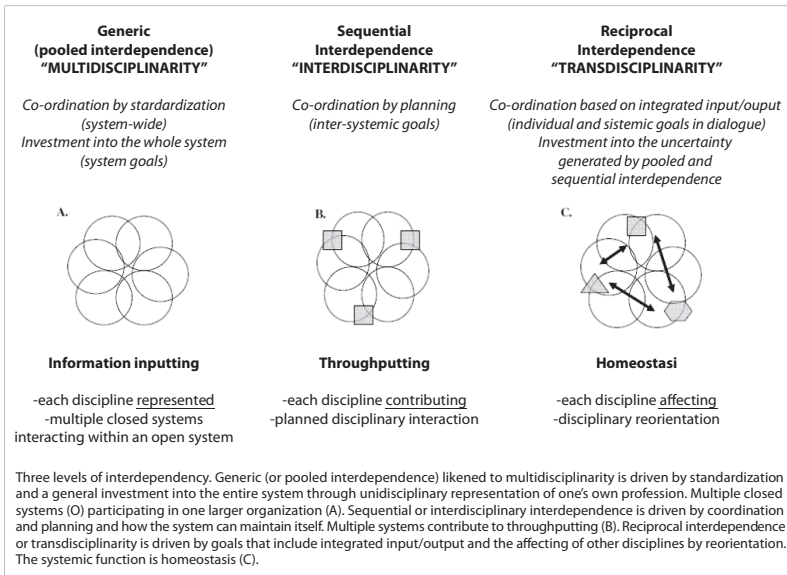


Figure 2. An Interdependent Model of Disciplinarity and Open System Qualities

TD knowledge is therefore what Basarab Nicolescu (2005) has coined, *in vivo* knowledge. It "corresponds between the external world of the object and the internal world of the subject ... including a system of values" (Nicolescu, 2005a, p. 7). Ikujiro Nonaka and Noburo Konno (1998) described it as "a shared space for emerging relationships" (Nonaka, Konno, 1998, p. 40). Several challenges are present in the process of achieving this environment. The first is *integration* in the act of TD learning which by its very nature invites novel exchange. Within its multiplicity, learners are engaged within a realm of complexity. "In order to navigate this exponentially growing complexity we need to develop tools of thought which use different logics, ones that include the subject and allow a wider view which can be used across all disciplines, allowing strategic points and knots of communication to be located" (Henagulph, 2000). Secondly, *praxis* becomes more normative as a model for integrating this multiplicity. Wickson, Carew and Russell (2006) state that TD and praxis "should co-evolve to a point where they are integrated and/or resonant. How this process proceeds in practice is one of the integrative challenges" (p. 1053) which has yet to be fully understood. Lastly, another challenge for TD environments is how to ensure *engagement* of ideas. Within learning endeavors, the challenge is to involve the learner in the theoretical,

epistemological, and methodological evolutions that are the source and summit of TD learning. Put another way, it is the commitment of the learning subject (individually and organizationally speaking) that ultimately affects this process through means of intention, autonomy, and fluctuation (Nonaka, 1994) which all possess some level of dynamism.

The challenge for both learner and leadership is “how to maintain some distance while working as an embedded [participant]” (Wickson et al., 2006, p. 1053). The TD environment provides a unique platform for considering the role of human agency, self-efficacy and ultimate mechanisms, which can be translated into leadership characteristics. It values the abilities of learners to disembody themselves from the disciplinary tenets which at times serve as barriers to crossing disciplinary dialogues while simultaneously serving as the means by which dialogue can occur. Cognitive, behavioral, and environmental factors are in tension or “reciprocal” relationship and affect each other bi-directionally (Bandura, 1977, 1986, 1999; Wood, Bandura, 1989). Though studies that provide empirical evidence of this phenomenon are rare, characteristics of TD settings can be arrived at using a complexus of theory from multiple sources which are all identifiable aspects of TD learning environments: *complex problem solving, praxis perspective, interpenetration of epistemologies, methodological pluralism, collaborative deconstruction, stakeholder involvement, open systems, and different (shifting) levels of reality.*

Table 1. Characteristic of Transdisciplinarity

Characteristics	Definition (Literature)
Complex problem solving	<i>Multidimensional, human and natural system interfaces, in the world and 'actual' versus "conceptual"</i> (Graybill et al., 2006; Wickson et al., 2006)
Praxis perspective	<i>Theory and application interaction</i> (Nicolescu, 1993, 1995, 1997, 1999, 2005a, 2005b; Pregering, 2006; Wickson et al., 2006)
Interpenetration of epistemologies	<i>Dissolution of disciplinary boundaries is necessary for novelty</i> (Kerne, 2005; Pirrie et al., 1998; von Bertalanffy, 1956; Wickson et al., 2006)
Methodical pluralism	<i>Respond to and reflect on problems in context; no single method</i> (Wickson et al., 2006)
Collaborative deconstruction	<i>Multiple approaches deconstructing and developing one another</i> (Kerne, 2005; Lambert, Monnier-Barbarino, 2005; Maaßen, Lieven, 2006; Simon, 1969; Wickson et al., 2006)

Stakeholder involvement	<i>Involvement as a means of investing in outcomes</i> (Barnett, Hallam, 1999; Fine, 2007; Maassen, Lieven, 2006; Wickson et al., 2006)
Open system	<i>Information exchanges across boundaries</i> (Buckley, 1967; Katz, Kahn, 1966; Klein, 1990, 1996, 1998, 2004, 2005, 2006a, 2006b; Nicolescu, 2005b; Tress et al., 2003)
Different (Shifting) levels of Reality	<i>Disunity in perspective</i> (Kuhn, 1970; Lawrence, Lorsch, 1967; Nicolescu, 1993, 2005a, 2005b; Thompson, 1967; Nicolescu, 1997, 1999)

Leadership processes

Within the last decade, complexity leadership theory (CLT) has proposed models focusing on broad types of leadership and their specific mechanisms (Uhl-Bien et al., 2007). Emphasis has been placed on the “micro-strategic leadership actions across all organizational levels and across organizational boundaries” (Lichtenstein et al., 2006, p. 2) and the self-organizing behaviors that enable change rather than focusing on control as a prime leadership characteristic (Marion, Uhl-Bien, 2001; Plowman et al., 2007). The role then of this complexity perspective is to supply a framework that on the one hand captures leadership in the task of establishing a “system where bottom up structuration occurs and moves the systems and its components to a more desirable level of fitness” (Osborn, Hunt, 2007, p. 332) and on the other hand recognizes that at the very least, top-down, middle-up-down, and bottom-up models all possess different knowledge perspectives (Nonaka, 1988). This task is challenging as it requires research that is equally focused on the manager and the management context in tandem. Many researchers are charged with considering this challenge without a real model for engagement, though some attempts have been tried (Aboelela et al., 2007; Lawrence et al., 2009; Simpson, 2006). Here we will focus on the model proposed by Uhl-Bien et al., (2007) that clearly suggests three discernable functions of leadership: administrative, adaptive, and enabling.

Administrative leadership

Administrative leadership refers the “actions of individuals and groups in formal managerial roles who plan and coordinate activities to accomplish organizationally-prescribed outcomes in an efficient and effective manner” (Uhl-Bien et al., 2007, p. 305). While this function of

leadership strives for clarity and resolution, it is equally seated within conflict as organizational patterns and standards emerge from the negotiations and goals of the organization. It is a topdown leadership mechanism and depends on authority and power for which to exercise its function. It provides certain overarching structures so that novelty and creativity can emerge. Even in CAS the administrative leadership function has as its focus the management of conflict and tension and views these as creative and critical components of new knowledge emergence.

Adaptive leadership

As emergent tensions and exchanges arise, the function of adaptive leadership is to harness the informal dynamics from interactive agents in CAS. “It originates in struggles among agents and groups over conflicting needs, ideas, and preferences; it results in movements, alliances of people, ideas, and technologies” (Uhl-Bien et al., 2007, p. 306). Unlike administrative leadership that commonly deals with symmetrical interactions housed within power and authority, adaptive leadership is often dealing with asymmetrical interactions which are the results of mixed realms of conflict (for example, authority and preference). In these cases, top-down leadership (administrative) is inadequate to achieve the changes and resolutions desired. What may seem as incompatible ideas or perspectives may ultimately be measurable units of innovation. Adaptive leadership strives to develop these into plausible and resolute outcomes. It is the interdependence of the various agents that contribute to the conflict and the ability of the adaptive leadership process to navigate these is its main characteristic.

Enabling leadership

The role of enabling leadership is both complementary to adaptive and administrative leadership functions as well as their culmination. While enabling assumes a more complex approach to dealing with conflict, allowing for emergence of new perspectives, it is also bound to the everyday and more mundane functions of leadership charged with efficiencies and outcomes. It supersedes adaptive leadership by its characteristic of “enabling effective CAS dynamics by fostering conditions that catalyze adaptive leadership” (Uhl-Bien et al., 2007, p. 309) and has a primary affect on entanglement fostering complex networks. It “fosters interactions, interdependency, and [injects] adaptive tension to help motivate and coordinate the interactive dynamic”. It is what

Nonaka and Hideo Yamanouchi argue as the essence of multi-stage organizational information creation including the creation of chaos, amplifying chaos, influencing dynamic cooperation, and restructuring organizational knowledge (Nonaka, Yamanouchi, 1989). In essence without enabling leadership (the synchronic culmination of all other functions), TD environments cannot be maintained.

Entanglement

Leadership processes within CAS are in combination. While some would argue that each is independently responsible for addressing different types of conflict (Simon, 1997), the behavior of CAS leadership processes assist in maintaining characteristically chaotic environments through entanglement. Kyriakos Kontopoulos (1993) has placed enormous emphasis on the importance of entanglement in interdependent systems such as these. "The combination of complex and compounded externalities, corporate and collective actors, and many-person systems lead to what may be called entangled interdependent systems" (Kontopoulos, 1993, p. 147). This process is a quantum mechanism that allows for the unstable and chaotic interchange of variables that are the units of measurement in TD environments. It takes into account the multiple types of functioning different variables play within a complex system. "One way to respond to these multiple and unruly variables is to look for those 'differences that make a difference' in the system. In addition, over time, the relevance, power, or interrelationships among differences may change" (Eoyang, Berkas, 1999, p. 4).

Different leadership processes and their interactions with different levels of the organizational hierarchy are instrumental in the establishment of a dynamic of throughputting (Katz, Kahn, 1966) where "the parts of the system (individuals, groups, institutions) are related to each other in complicated and unpredictable ways. These systems demonstrate cross-current causality" (Eoyang, Berkas, 1999, p. 4). Leadership functions become therefore free from their independent constraints and *entangled* into the multi-level constructs of an organization to produce a chaotic relationship or space ("ba") free to generate new channels for emergent knowledge (Nonaka, Konno, 1998).

Heterarchy

Heterarchy, the figurative space somewhere between the extremes of anarchy and hierarchy, drives the leadership influences within these multi-level social environments—the edge of chaos. Here lies the kernel of theory for novel and emergent knowledge grounded in conflict and leadership intervention. “The major problem that any satisfactory heterarchical theory of social structure has to resolve is the discovery, elaboration and classification of all the logics involved in these processes of more complex, intersected structurations” (Kontopoulos, 1993, p. 238). Kontopoulos provides a patterned description of the interplay between levels of leadership logic (adaptive, administrative, and enabling processes) and their interface through the chain of hierarchical exchanges (the micro-, meso-, and macro-level organizational structures). This heterarchical mechanism allows for leadership processes entangled and enmeshed into the various levels of organizational hierarchy to contribute to the emergence of new knowledge that is not bound simply to any one process or one hierarchical structure. Through the “entanglement of levels there is no way of telling once and for all that one level is superior to or casually more important or ontologically more basic. Hierarchy means complete inclusion and suppression; heterarchy means partial inclusion and tangledness” (Kontopoulos, 1993, p. 63).

Leadership interventions

Regardless if one subscribes to the bottom-up structuration concept (Osborn, Hunt, 2007) or that of multi-model leadership awareness (Nonaka, Konno, 1998), leadership functioning through entanglement directs conflict derived knowledge through manageable and efficient agents throughout the multiple levels of an organization. “A complex systems perspective introduces a new leadership ‘logic’ in terms of an emergent event rather than a person ... in an interactive dynamic, with which any particular person will participate as leader or a follower at different times and for different purposes” (Lichtenstein et al., 2006, p. 133). This approach adopted by Hannah and Lester (2009) maintains that amidst positive control over knowledge complexity the main task of the enabling leadership is that adaptability may be systematically maintained. The authors use a micro-, meso-, macro-level social structure (Smelser, 1995) to explain.

Micro-level interventions

On the micro-level, individual learning is the primary focus. Fostering readiness to learn and promote learning in individuals is done through catalytic agents that are “cognitive processes that ultimately result in lasting changes to mental models” (Hannah, Lester, 2009, p. 36). Leadership intervention on this level has the ability to secure certain conceptual frames, support connections, and affect long term memory. Furthermore, knowledge acquired on this level is relational as concepts and models emerge in relationship with others that over time can potentially lead to new perspectives. The authors propose that it is at this level where positive control over knowledge can result in the monitoring of “developmental readiness as both the ability and motivation to, make meaning of, and appropriate new knowledge into one’s long term memory structures” (p. 37). Leadership influences learning through targeted developmental experiences leading to increased learning efficacy and ultimate metacognitive abilities critical for “managing new knowledge and adapting mental models” (p. 38).

Meso-level Interventions

The precursory level preparation afforded on the individual level allows for further development for social networks of knowledge to emerge. Here, on the meso-level of the organization, promoting and facilitating effective knowledge-centric social networks is the focus. Social networks serve as critical catalysts to the emergence of new knowledge. They “maintain intricate architecture, have nonlinear and discontinuous relationships between members, and will adapt to both internal competition for resources and external influences” (Hannah, Lester, 2009, p. 40). Within this level of interaction meaning emerges as the conduit for knowledge to be shared and tested by agentic forces. “The behaviors of ensembles [networks] should be analyzed as products of the actions of independent variables, as has traditionally been the case, *and* of interaction among different ensembles” (Marion, Uhl-Bien, 2001, p. 393). Knowledge retains meaning once understood in light of other knowledge, and this understanding provides for a dynamic characteristic necessary within CAS. Leadership serves less here as a means by which knowledge is controlled and more so as a social attractor allowing for exchanges to perpetuate. Leadership takes on an integrative approach on this level, “dynamically fluctuating influence patterns over time as the agents involved engage in dynamical search among influences that are functions of inter-agent dynamics,

organizational adaptation, and competitive performance in a changing competitive context” (Panzar et al., 2007, p. 308). On the meso-level, quality becomes an important factor as the desire to enhance and improve the functioning of networks becomes a characteristic of leadership. This desire is operationalized by embedding key knowledge catalysts into the network, increasing network density, or linking knowledge catalysts by establishing bridges between semi-autonomous networks (p. 41), loosely coupled systems (Weick, 1976), or neural networks (Kontopoulos, 1993).

Macro-level interventions

Macro-level interventions transcend the process of attracting agents within networks and move to the scanning, sanctioning, and institutionalizing critical emergent knowledge using specific leadership and management practices. Enabling leadership is most effective in achieving this function. While the interpretation of Hannah and Lester (2009) seem to suggest that this is accomplished through senior management, an agentic approach can still be assumed. Within this level of “system-wide leader actions” the micro- and meso-levels become part of the scaffolding which provides for “rich fields of emergent knowledge” (p. 43) as system level processes are routed from within by individual and network oriented clusters. Visioning, balancing exploitation and exploration, managing time diffusion, and codifying resources are characteristic mechanisms on this level. The interrelatedness between the three levels on this system-oriented plane is key to the emergence of this new knowledge as it is necessary for adaptation across multiple systems.

Knowledge feedback loop

What has been presented thus far contributes to a model constructed to support mechanisms of leadership within TD environments as they describe a system of emergent knowledge and of sustainability. In this section, the *knowledge feedback loop* is introduced as a means for understanding the relationship between leadership and heterarchy and their roles in establishing a continual state of dynamic periodic and aperiodic change. See Figure 3.

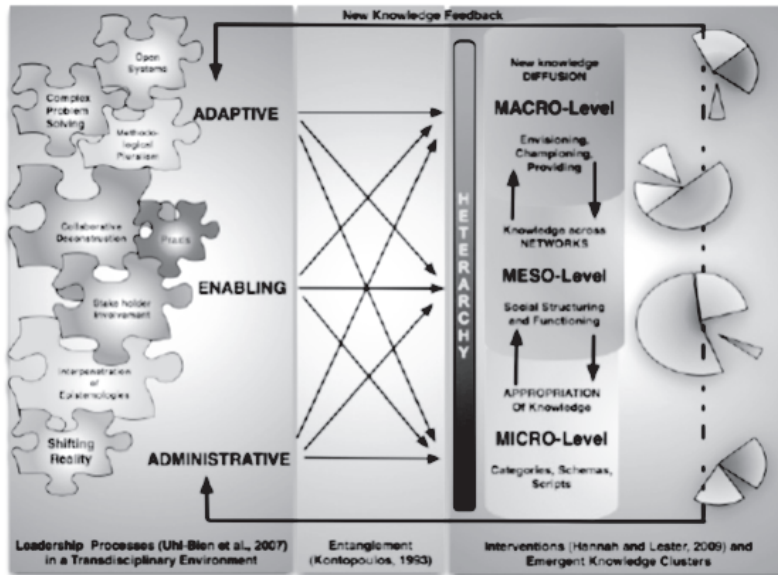


Figure 3. Complexity Leadership in Transdisciplinary (TD) Learning Environments with a Knowledge Feedback Loop

The concept of evaluation in this model, recognized as the feedback loop, is grounded in a concern with the unpredictability of behavior within CAS and the need to retain its dynamism so that adaptive knowledge can serve as a means for interchange. Glenda Eoyang and Thomas Berkas have argued that an evaluator should “1) capture an emerging mode of casual relationships, 2) evaluate and revise the evaluation design often and 3) capture, preserve and learn from the “noise” in the system - the unexpected as well as the expected, the long and shortterm outcomes and the close and distant points of view” (Eoyang, Berkas, 1999, p. 3-4). It is what Nonaka’s model of organizational information and knowledge creation suggests but within a framework of continual changing and shifting TD characteristics.

“The evaluator cannot realistically consider an organization or a program to be moving in a predictable way toward a pre-determined end point. This means that social systems, as CAS, do not move inexorably toward a project’s end point, and they may not come to rest even when the end of a project is reached. An evaluator may be able to assign an arbitrary beginning and end date of an intervention, but the system itself recognizes no such boundaries in time. For this reason, the whole concept of

projected and predictable outcomes is an artificial construct when evaluating performance in a CAS” (Eoyang, Berkas, 1999, p. 2).

For Nonaka the information creation process serves as a response to the changing environmental or organizational chaos that instigates a need for using that chaos as a rich resource for learning. Chaos is not meant to be eliminated in his model but rather “actively generated to expand the possibility of taking in chance information. And at the same time, diverse systems and modes of behavior that will inevitably connect these must be allowed to coexist” (Nonaka, 1989, p. 307). But even here, the management of chaos and instability is a means by which to ultimately return organizational knowledge to a stable state, if only temporarily. Within TD environments the *return loop* component of these environments contributes more constantly to its dynamism and helps to maintain the TD environment (in its continually adaptive state). Themes of interpenetration of epistemologies, pluralism, shifting realities, and deconstruction, etc. are in themselves stable TD structures by the nature of their dynamism and hence are uniquely characteristic of TD environments.

This stated, the model proposed in this paper highlights TD dynamism as a condition necessary for different leadership processes (Uhl-Bien et al., 2007) to influence multi-level organizations (Hannah, Lester, 2009) through interventions of entanglement (Kontopoulos, 1993) ensuring the *return loop* of new knowledge generation as a constant learning experience. Moreover, this new knowledge serves as a means by which the feedback loop to the perpetually unstable TD environment contributes to a constant and innovative engine of knowledge creation. “People and their knowledge are the building blocks from which new knowledge can be created. They are the fuel of the whole engine. Learning, supported by knowledge management, is the mechanism that enables knowledge creation, increasing knowledge depth and diversity, from which personal insights and synergistic discovery occurs speaking the innovation process” (Correia de Sousa, 2006, p. 404).

Conclusion: challenges and application

The argument here has two main intentions: 1) it is an attempt to shift our attention to interactions as *foci* of measurement, away from individual actors; and 2) it has underscored the emergent nature of knowledge as

a chief agent in CAS. This new knowledge framework harbors not only new perspectives on leadership but moreover highlights the elastic and creative enterprises within CAS and a possible manipulation of its energy to maintain continuously reoccurring knowledge generation and feedback that informs TD environments. These replace the more structural and functional attributes that the industrial age has perpetuated.

While much of complexity science has been focused on CLT and how it informs workplace settings in this new framework, equally needed attention should be applied to leadership within educational environments where internal and external demands and constraints specific to educational systems are similar to those found in industry. Like industrial managers, educational leaders are confronted with being both autonomous and interdependent and ensuring that the interchange of knowledge performs accordingly (Stacey, 2007). The purpose of educational leadership is to ensure that the “application of new knowledge includes institutionalizing it in a way that retains it as long as it remains relevant [and] encourages, facilitates, and sustains a favorable level of innovation and collective learning” (Yukl, 2009, p. 49-50). Individual leaders can be interpreted as the *catalysts* that possess the ability to affect organizational learning through social interactions in countless ways. Some studies have even gone as far as to suggest that innovation as a core element in organizational learning depends on the managerial leader and his or her role as a futurist, integrator, and strategist; (Savage, Sales, 2008) or as a transformational agents operating within frameworks that focus on the role of the manager and their intuiting, interpreting, integrating, and institutionalizing skills (Crossan et al., 1999). However, others continue to propose that leadership theories that focus on the leader and individual functioning and characteristics are too constricted to capture the necessary dynamics associated with the management of new knowledge. In research, CLT forces us to focus on the

“Space between: identifying and bracketing the events, episodes, and interactions of interest; capturing these events or interactions as data in systemic way; gathering individual/agent level data that describe interaction cues received over time; modeling these data in ways that highlight their longitudinal and relational qualities; and analyzing these data in terms of their relational qualities and longitudinal dynamics” (Lichtenstein et al., 2006, p. 137).

David Mansfield has argued that leaders in complex educational environments “must be prepared to find new routes to agreed destinations, and not be afraid of getting lost, trusting that the edge of chaos is the grounds of real creativity and development for all” (Mansfield, 2003, p. 3). This element of chaos is the social environment that “encourages the use of procedures that increase creative ideas, nurturing promising ideas that are initially vague or controversial, obtaining resources needed to develop ideas, analyze team processes, and monitoring events that are relevant to innovative activities by the team” (Yukl, 2009, p. 51). Leadership in this context is therefore grounded in the dynamic tension between exploration and exploitation (March, 1991). Yukl (2009) states that these are not separate unrelated processes but are in dynamic tension within educational environments and leader’s need to guard against over emphasis in either arena lest they be in constant conflict in the attempt at generating new knowledge (Yukl, 2009). Jansen, Vera, and Crossan (2009) have debated leadership roles in light of this and have propose that while transformational leadership is instrumental in instilling exploratory innovations in workplace environments; it is limited in its ability to maintain both exploratory and exploitative mechanisms. For the latter, more transactional behaviors are required. They also argue that environmental dynamism, like that in CAS, is the central variable element that supports the creation of new knowledge, rather than individual centered leadership.

“Our study revealed that a negative effect of transformational leadership on pursuing exploitative innovation as well as more negative relationship between transactional leadership and exploratory innovation emerges when we took environmental dynamics into account. Our study provides strong support for the notion that *misfits* rather than *fits* matter between leadership style and innovation outcomes in changing environments” (Jansen et al., 2009, p. 15).

Educational leadership therefore is faced with a number of obstacles most of which are grounded in limited and constrained approaches in dealing with the dynamical landscape of CAS. The proposed model addresses these obstacles in different ways. First, according to Yukl, is the obstacle that individual leaders are responsible for leading change and innovation. “This encourages a top-down approach, rather than a collaborative approach that includes emergent processes” (Yukl, 2009, p. 52). It

would seem then that complex elements in the learning system could be limited by the abilities of leadership to manage its dynamism. As has been shown, even within the top-down administrative function, through the function of entanglement, leadership need not be constricted by limitations since the agent may intervene on all three levels of the social construct. Leadership contributes to the structuring and integration of the system's elements that are not limited by the agent itself. Rather, it contributes to the system's ability to "differentiate, grow, or expend energy" (Schwandt, 2008).

Second, collective learning is often disabled by restrictions in the sharing of knowledge which are the direct result of leadership blocking inclusion (Yukl, 2009). This power orientation can be imbedded in a variety of leadership approaches, but in all cases where leaders serve as the gatekeepers of knowledge access "power and accountability are intimately connected with one's knowledge and use of the rules and with the law like form of administration that this implies" (Morgan, 2006, p. 152). It is safe to assume that this type of control can be exercised in a variety of ways and by all three leadership processes discussed. However, the model suggests that even if control over knowledge is exercised within certain leadership functions, the heterarchical intervention environment can serve as a delimiter as influence is dissipated through exchanges in the organizational hierarchy.

Third, differentiation between subunits within organizations can result in lowered cooperation. Transdisciplinarity requires a reappraisal of integration and also a reconsideration of the systems that it brings together. It must be internally differentiated to achieve integrative properties making it able to respond to its environment. If there is no interdependence, there is no need for coordination (Lawrence, Lorsch, 1967). Kontopoulos argues that this is where different modalities of interaction need to be considered. He suggests different identifiable modalities (interactive-strategic, interactive-communicative, quasi-interactive, and nearly noninteractive) that have significant influence on the process of measuring interactions (Kontopoulos, 1993). Each, differing in degree, has as its basis the knowledge properties of interdependence.

Lastly, conflict between stakeholder's objectives and goals can serve as barriers to learning opportunities especially when new knowledge is introduced (Yukl, 2009) even though the thesis here might allude otherwise. Rounce, Scarfe, and Garnett have shown this in their study of work-based learning approaches in senior health care professionals.

They found that to be effective across multiple pathways, context, partnerships, and language, the developing of a curriculum was severely affected by stakeholder tensions. Their results focused on managing the complexity, the importance of planning, purpose and outcomes, and where authority rests in the decision-making process (Rounce et al., 2007). The model proposed takes into account the tensions and exchanges that emerge from multiple stakeholders found within the leadership spectrum and allows for multiple interests to become part of the overall knowledge creation matrix. It further accentuates the importance of looping the knowledge that emerges from these interactions back into the TD environment.

The conclusion that a knowledge feedback loop is critical to the sustainability of complex adaptive systems, especially those striving for innovation through transdisciplinary learning, is somewhat obvious. The input of knowledge yields greater and improved knowledge. This outcome is not a result of a new paradigm *per se*. Rather, knowledge as the catalyst for regeneration of structures, the result of shifting perspectives about leadership and adaptability affecting the structure itself, that serves as throughput and not merely desired output is novel. It presents a fresh consideration about the role of leadership, especially the type of leadership that is charged with generating new and emergent knowledge.

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Sintesi

Rispetto all'epoca industriale dominata da modelli di leadership in cui prevaleva la centralità degli individui, nell'età della conoscenza il mutamento radicale di paradigma riconosce al "concetto esteso di leadership" un ruolo determinante nei processi che influenzano le organizzazioni, collegandolo strettamente alla complessità, al dinamismo e all'innovazione. "La leadership nella complessità" risulta in tal modo essenzialmente adattiva ed emergono, quali attributi chiave, l'instabilità, l'irregolarità, la tensione dinamica, le differenze e il disordine.

Nella ricerca statunitense proposta, simultaneamente teorica e applicativa, si delinea così un modello di conoscenza fondato su sistemi adattivi complessi (CAS), nell'ambito di scenari transdisciplinari, in cui la conoscenza è insieme il catalizzatore e il prodotto dell'intero sistema: con il superamento degli approcci psico-cognitivi, infatti, negli ambienti di apprendimento transdisciplinari l'accento si trasferisce completamente sulla pluralità complessa e sulle interazioni; l'azione sociale diventa pertanto il motore dell'innovazione e della creazione di conoscenza.

Ben oltre la multidisciplinarietà e l'interdisciplinarietà, la transdisciplinarietà assicura l'"impollinazione incrociata" fra le discipline - vale a dire la loro metodica contaminazione, scambievolmente e feconda - e nel contempo una rappresentazione più olistica e dinamica di scienza.

Si a CAS che la transdisciplinarietà sono contraddistinti peculiarmente dall'interdipendenza reciproca, cui corrisponde, quale funzione sistemica, l'omeostasi.

Si possono individuare alcune caratteristiche fondamentali degli ambienti di apprendimento transdisciplinari:

- il problem solving complesso;
- una prospettiva di praxis, intesa come interazione di teoria e applicazione;
- l'interpenetrazione di epistemologie;
- il pluralismo metodologico, che esclude coerentemente il ricorso ad un unico metodo;
- la decostruzione collaborativa, e cioè approcci multipli che decostruiscono e si sviluppano l'uno dall'altro;
- il coinvolgimento degli stakeholder;
- i sistemi aperti;
- i diversi livelli di realtà, in movimento e in mutamento continui.

Al dinamismo transdisciplinare fa riscontro una molteplicità di processi di leadership, i quali esigono interventi multilivello, per garantire ininterrottamente la generazione di conoscenza e dunque la costanza dell'apprendimento.

Per la sostenibilità dei sistemi adattivi complessi, finalizzati all'apprendimento transdisciplinare diviene perciò decisivo "un feedback di conoscenza continuo", che assicura il loro costante rinnovamento: solo grazie ad esso, infatti, da un lato la conoscenza permane stabilmente quale catalizzatore per la rigenerazione delle strutture e dall'altro la leadership assolve il compito di produrre incessantemente conoscenza, creatività e apprendimento.