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Chapter

Complex Adaptive Team Systems (CATS): Scaling of a Team Leadership Development Model

John R. Turner, Rose M. Baker and Kerry Romine

Abstract

Complex adaptive systems (CAS) have been identified as being hard to comprehend, composed of multiple interacting components acting interdependently with overlapping functions aimed at adapting to external/environmental forces. The current theoretical model utilized the natural functions of teams, viewing teams as a complex adaptive system, to develop the structure of the theory of complex adaptive team systems (CATS). The CATS model was formulated around the components of complexity theory (interactions, nonlinearity, interdependency, heterogeneity, complex systems, emergence, self-organizing, and adaptability) to show its utility across multiple domains (the role of leadership, organizational learning, organizational change, collective cognitive structures, innovation, cross-business-unit collaborations). In theorizing the CATS model, a new level of analysis was implemented, the interactions between agents as a move toward emergence in complex systems. The CATS model ultimately provides a model for organizations/institutions to drive knowledge creation and innovation while operating in today's complexity.

Keywords: complexity, teams, complex adaptive systems, complex adaptive team systems, interactions

1. Introduction

With team research becoming more prevalent across disciplines [1], there remain some unresolved issues. One unresolved issue is in conceptualizing or theorizing teams as complex adaptive systems (CAS; [1]). Even though this advancement in conceptualizing teams as CAS has started to gain momentum, empirical research has yet to catch up [1]. One advantage of viewing teams as CAS is that it better positions research and theory building efforts in a team's natural setting, occurring closer to the phenomena [1]. Complex adaptive systems adapt and change due to environmental conditions thus making them dynamic and challenging to understand [2]. Due to this self-organizing adaptation, models of CAS are lacking and are "hard to formulate" [2]. Complex adaptive systems are also hard to comprehend in that these systems are not just the aggregate of the actions of the individual parts; it is the composite of the interactions of the parts [2]. deMattos et al. [3] expressed this by highlighting complexity as the result of "the inter-relationship, inter-action, and inter-connectivity of elements within a system". To better understand CAS we must be able to understand how behaviors emerge from these interactions [2].

The composite of these interactions within CAS is often a function of leadership. Leadership in CAS is based on driving and facilitating these interactions. Leadership, in this perspective, "is about inter-action, influencing others, and encompasses a relationality that is dyadic and networked" [4]. Within CAS, leadership often takes the form of shared leadership in which individuals, or team members, share power and roles with other members based on task and situational demands [5]. Leadership for CAS has also been found in boundary spanning in which the leader establishes required interactions with team members and external agents when needed [5]. For each type of leadership style, leading in CAS requires a change in focus, redirecting the flow of practice toward new interactions and in new directions [4].

The current theoretical article provides a model for CAS by utilizing an existing team model, the Team Emergence Leadership Development and Evaluation (TELDE) model [6]. Identifying teams as CAS, the TELDE model helps to conceptualize the behaviors and interactions that take place in a team setting to understand, drive, and predict these emergent transformations. As emergent transformations are a response to environmental forces, teams are better able to adapt and share resources to achieve a new entity to better manage these new external changes, thus requiring leadership to also share roles and resources. The theoretical model presented in the current article utilizes naturally occurring team functions as the structure (TELDE) for CAS. Collectively, these CAS that utilize the TELDE model as its structure has the potential of scaling to the broader organizational, industrial, or community levels. The theoretical model presented here is titled Complex Adaptive Team Systems (CATS). The CATS model utilizes natural occurring team functions to drive more substantial organizational activities, such as the implementing knowledge management functions [7].

The style of theorizing for the current article is the narrative style of theorizing [8, 9]. The narrative style to theorizing is in response to recent calls from researchers to add more diversity to theory development styles that are currently published [8]. Also, the narrative style to theorizing is advantageous when the goal is to show patterns and to make broad connections, providing the ability to "see the big picture" [9].

The following sections provide a review of complexity theory and some of its key components. Next, a coverage of CAS is provided with a look at utilizing interactions as the level of analysis when viewing CAS. Finally, a review of the TELDE model is presented along with a model of CAS that utilizes the TELDE model and natural occurring team processes. This model, the Complex Adaptive Team System (CATS) model, provides the structure that organizations can implement when addressing today's complexity.

2. Complexity theory

Borzillo and Kaminska-Labbe [10] highlighted enabling leadership for communities of practice, indicating the role of leadership is to create situations that increase the social interactions of individuals. Here complexity theory addresses knowledge creation by facilitating the number of interactions or connections among agents. Within organizational settings and from a learning organization perspective, Borzillo and Kaminska-Labbe [10] identified the leaders' role as being one that increases connectivity for the enhancement of cooperation and learning. Complexity theory has seen growth within the leadership literature: strategic leadership [11]; managerial leadership [12]; organizational leadership [13]; in viewing leadership as an *emergent, interactive dynamic* [14]; and for viewing the dynamic and distributed nature of leadership [15].

2.1 Complexity theory primary components

2.1.1 Interactions

Anderson et al. [16] identified complexity in the interactions between individual parts of an open system and to the unpredictable patterns that emerged from these interactions. Antonacopoulou and Chiva [17] identified both interaction and interdependence processes across different levels (i.e., individual, team, department, organization) as being critical to emergence in complex systems. These functions highlight individual agents and their social structures as being synonymous with fractals, they have the potential to operate both as a part of the system and as a whole at the same time [17]. Understanding complexity and the systems that make up social complex systems is essential in making sense of the dynamics leading to the interactions, resulting in interdependence between agents or systems [17]. Complexity theory, or complexity science, is viewed as being one method to investigate the properties and behaviors of these non-linear dynamic systems [3].

2.1.2 Non-linear distributive pattern formations

A distinction between complex and chaos systems is in order. Complex systems are non-deterministic whereas chaos systems are deterministic [13], however both are non-linear systems. Non-deterministic systems provide no means of predicting future states while deterministic systems allow for prediction of future states. Complexity theory is:

> *A study of changing patterns of order, self-organization or constrained diversity. Complexity arises from chaos theory [18] which first identified how order can be found in disorder (chaos). Chaos theory, in this sense, describes a mathematical concept that delineates how within different systems, patterns appear but in a random fashion. [16]*

Complexity theory is also useful for understanding nonlinear systems [13, 19, 20]. Similarly, complex systems have been described as exhibiting *butterfly effects* in which a small change in the system could potentially lead to a large change overall [12, 13, 19]. Likewise, Crawford and Kreiser [21] identified the power law effect in which changes at one level can result in extreme changes at other levels within the system and Hammer et al. [22] described complexity as being a "perturbation, or disturbance, to a system". Burgelman and Grove [23] identified nonlinearity as being a property in which the magnitude of the output is not linearly related to the input.

2.1.3 Interdependent, heterogeneous, and autonomous agents

Complexity theory provides a framework for understanding complex systems by identifying and recognizing the behaviors of interdependent, heterogeneous, and autonomous agents or systems. Here it is the patterns of the interactions from autonomous agents acting interdependently within a network or system that are under investigation [10]. Hunt et al. [12] identified emergence resulting from the interdependence of agents and their components. Hanseth and Lyytinen [24] placed complexity in the field of information technology (IT) as being related to increasing heterogeneous components and their relationships, dynamics, and interactions. Likewise, Uhl-Bien et al. [14] highlighted heterogeneous agents interacting in networks that produce patterns of behavior.

2.1.4 Complex versus complicated systems

Bode and Wagner [25] defined complex systems as those with a variety of parts that interact in unpredictable ways. Expanding upon this definition, Bode and Wagner [25] separated complexity into two conceptualizations, structural and behavioral. Structural complexity related to the number and variety of the elements while dynamic complexity (behavioral) related to the interactions between the systems' parts or elements [25]. Similarly, Mowles [26] identified three kinds of social problems when viewed from the lens of complexity theory: simple, complicated, and complex. Simple problems relate to those that can be solved using known recipes, complicated problems consist of many sub-problems that can be resolved collectively to solve a bigger problem, and complex problems have no recipe or formula with changing variables [26] and often require dynamic solutions as the problem's variables change.

Anderson et al. [16] acknowledged that complex systems present a lack of predictability due to the interactions that take place among the components of a system. These interactions produce unexpected change compared to complicated systems that do not involve multiple and multi-level interactions within and among the system components, thus reducing the potential for systemic change from occurring. Complicated systems are predictable, and their components are either managed or designed to perform specific functions [16]. Bode and Wagner [25] identified that the more complex a system, the number of elements increase along with a rise in the number of potential interactions between the elements, resulting in a variety of different states that the system could exhibit at any one time.

Complex systems also produce higher levels of uncertainty or ambiguity. Mowles [26] identified four levels of uncertainty as being: a clear enough future, alternative future, a range of future, and true ambiguity. The latter levels of having either a range of futures or true ambiguity relate to the dynamics of complexity [26]. As the level of uncertainty and ambiguity increase, strategy requires processes to become intertwined [26] due to the interconnections and dynamism within the sub-systems [16]. As the level of complexity increases, it becomes more essential for leadership to be more distributed among agents of the CAS as no one individual can be expected to be an expert on all tasks and activities required of the CAS [27].

2.1.5 Emergence

Different domains can emerge within the same system, organization, or institution given the right circumstances. Richardson [28] described a domain as an autonomous structure that is different from the whole, also identified as *noise*. Domains emerge under differing circumstances and environmental factors, each with their life cycle [28]. These domains appear to be spontaneous with no structure or organizing features. However, through closer investigation these emerging entities, or domains, have structure, are self-organizing, develop distinct patterns [28], and persist until its usefulness abstains or a new emergent entity replaces it. A domain's structure moves from equilibrium to a state of disequilibrium, changing its original adaptive functions, during this emergence [29]. The literature also described this phenomenon as *adaptive tension* that differentiates energy between the system and its environment as factors that drive self-organizing and emergent functions [10, 15]. Being able to arrange one's components autonomously in response to external disturbances, using self–organizing functions as opposed to top–down directives, describes the phenomenon of emergence best [29]. Here, Beck and Plowman [29] connected self-organizing systems with emergence, meaning that a system must be self-organizing (open) before it can experience emergence. Uhl-Bien et al. [14]

described two characteristics of emergence, the reformulation of existing structures into new elements and its ability to be self-organizing [12].

While CAS (e.g., teams, organizations) operate between the state of equilibrium and disequilibrium, they may appear to be operating randomly. However, this false perception of random behavior is the emergence that "guides agent-based systems to potential new levels of collective behavior" [11]. Complex adaptive systems have been viewed as a *complexity region* operating between the "edge of order" and the "edge of chaos" [10]. These CAS transcend or evolve when on the edge of chaos, also identified as *limited instability* [30], and as *the paradox of control* [15], up to the point where some form of equilibrium sustains between stability and chaos. This emergence cannot be programmed or managed into the elements of a system; rather emergence is a product of the interaction between the elements [19].

This concept of emergent domains can be both positive as well as negative. For example, teams are utilized in the workplace to perform functions that individuals are unable to do on their own. The resources, collective experience and knowledge, afforded by functional teams, aid in the team's overall outcome. In some cases, this outcome is not only better than expected, but it can often be unexpected as well, making the team process one of emergence. Likewise, emergence can also be detrimental, making things more complicated. Take for example the concept of wicked problems. Aagaard [31] identified wicked problems developing through turbulent environments with continually changing expectations and solutions. These constant fluctuations present problems with ever–changing variables being derived based on the current environmental conditions, as environmental conditions change so to do the variables. These cyclical dynamics could be viewed as a form of emergence that reformulates a problem organically as environmental conditions fluctuate. Addressing wicked problems requires organizations and institutions to become more adaptive in their problem-solving methodologies [31]. Wicked problems have been viewed as being influenced by CAS where institutions, "such as nations, oil companies, and utilities are important actors" [32]. Traditional problem defining practices are not practical when addressing wicked problems. Here, one addresses wicked problems with an understanding of adaptability, emergence, and interconnectivity.

2.1.6 Self-organizing and adaptability

The function of self-organizing is a process [33], one in which the components of the system communicate with each other and cooperate in their coordinated efforts. This self-organizing process is critical to the emergence outcome, a co-creator of emergence [33]. Adaptability is vital in that self-organizing processes allow for systems to become adaptable and react to both external (environmental changes) and internal (organizational policies and processes) forces, leading closer to emergence. Also, this adaptability leads to a system being open and non-linear as compared to a closed and linear system. Chiva et al. [30] described adaptability as a "system's capacity to adjust to changes in the environment without endangering its essential organizational features". Adaptability is what differentiates closed systems from open systems; closed systems maintain the status quo while open systems adapt to external forces [34]. This distinction, between closed and open systems, is an important one. Closed systems can be self-organizing; however only open systems can be adaptive through self-organization without any external (managerial) intervention. However, there are times when an organization's features do change after adaptability forces react, this is where emergence comes into play. Emergence changes the system's structure to a new transformed structure allowing it to better adapt to external forces.

3. Complex adaptive systems (CAS)

Organizations are complex systems made up of interdependent agents [11, 29] with overlapping functions. These complex systems can often be identified as networks, projects, hierarchies [31], teams, task forces, and departments to name only a few. Anderson et al. [16] identified entrepreneurship as being a complex system in which individual entrepreneurship efforts aggregate into the macroeconomy, with each micro process being unique, self-organizing, and different from the next. Alternatively, Aritua et al. [35] called on the profession of project management to develop new techniques and methodologies by viewing multi-projects as CAS. They identified one problem was with the field treating multi-projects as the aggregate of single project techniques and methodologies, which has not been very successful.

Complex adaptive systems are composed of individual actors acting interdependently, and autonomously [19], toward common goals. These CAS also learn through interactions and adapt behaviors based on this new knowledge [29], with the ability to evolve and self-organize [24]. Complex adaptive systems are the building blocks for higher level agents or systems (e.g., organizations, economies) while continuously adapting to environmental changes, called *phase transitions* [33]. They are dynamic and direct energy to sustain the system's activities and structures [19]. Simon defined a complex system as "one made up of a large number of parts that interact in a non-simple way" (as cited in [36]) while utilizing heterogeneous interactions among one another and external elements [30]. The following definitions of complex adaptive systems from the literature follow.

3.1 Definitions of CAS

Complex adaptive systems are responsive systems consisting of multiple agents that "cannot be created, designed or controlled by individual actors. But the system can be influenced, nurtured and exploited by a group of actors" [31]. This responsive aspect refers to the ability of the agents to act freely [16], interdependently [31], to learn and adapt [3, 29], and are linked dynamically [14]. Agents within CAS interact in response to internal and external threats, producing both complex and adaptive behavior patterns [11]. The interactivity among independent agents makes complex systems difficult to predict [36]. Patterns, or outcomes, are unpredictable and non-linear [21] due to the nature of complexity involved and the interconnectivity across the sub-systems. Emergence results from these interactions in which a new system evolves from constant revising and rearranging the system components [33], providing the system with new capabilities of addressing internal and external threats.

The following definition for CAS will guide the theoretical model presented in the current research:

> *Neural-like networks of interacting, interdependent agents who are bonded in a cooperative dynamic by common goal, outlook, need, etc. They are changeable structures with multiple, overlapping hierarchies, and like the individuals that comprise them, CAS are linked with one another in a dynamic, interactive network [14].*

3.2 Characteristics of CAS

Complex adaptive systems, in its purest form, have been characterized as systems exhibiting characteristics of complexity theory [35]. For example, within the strategic management literature researchers identified the concept of strategic renewal as: "The incremental process through which an organization continuously adapts to the environment and explores opportunities to invoke change in its activity choices and outputs" [36]. As an evolutionary process, renewal occurs from relational exchanges (interactions) that provide organizations with systematic methods of addressing environmental change [37]. Strategic renewal views activity systems (e.g., CAS) from either an inertial view or from an adaptive view [36, 37]. The inertial view concentrates on the distribution of interdependencies (pattern) while the adaptive view focuses on information and resource flows (rules):

1. the interdependency pattern, the relative distribution of interdependencies among a focal firm's activities, and

2. the interdependency rules, the prescriptive guidance of resource and information flows among interdependent activities [36].

Within the strategic management literature, it is the interdependency that enables strategic renewal in organizations [36]. Activity systems are complicated, in part due to their degree of modularity, concentration, and openness [36]. Modularity involves the number of subsystems within each system, concentration involves central control in one subsystem affecting other peripheral systems, and openness relates to one system's dependency in making its own decisions, procedures, and policies separate from the other systems [36]. The more interdependent and interactive these components become, the more complex the system.

In the organizational learning literature, Antonacopoulou and Chiva [17] highlighted something similar to strategic renewal. They described the process of interdependence as a balancing act in which agents co-exist and co-evolve simultaneously. Interdependence allows processes to navigate between stability and change as part of an adaptive process. Complex adaptive systems have been identified as having the following essential components: "diversity and individuality of components, localized interactions among those components, and an autonomous process that uses the outcomes of those interactions to select a subset of those components for replication or enhancement" [3]. Similarly, Gregory et al. [38] and Hammer et al. [22] identified a total of 16 characteristics of CAS categorized into four facets: continuous varying interactions (CVI), patterns development (PD), people factors (PF), and self-organization (SO). The CVI facet involves types of interactions, the PD represents patterns that emerge from these interactions, the PF represents humans as social systems and, SO is constantly present in the background of the CAS [22].

Inter-relationships are common in social systems when taking a systems theory point of view. However, while systems theory mainly addresses closed and simple systems, complexity theory addresses complexity in open systems via CAS. In contrast to closed systems that do not interact with their external environment, open systems do. The more open a system becomes, the more it is affected by changes in its external environment. Just as individuals act in similar ways to those in proximity, the same could be said about other systems. Groups act similarly to other groups in proximity (i.e., organizational departments, executive boards), organizations act similarly to other organizations in proximity (i.e., industry, sector), communities act similarly to other communities in proximity (i.e., sister cities, smart cities), and so on. Emergence occurs when a set of individuals, as in a team setting, combine efforts to develop something positive, innovative, and unexpected. The same is true when multiple groups get together, when organizations get together, when governments get together, and so on. This perspective, that emergence can yield from interactions among collectives, has been highlighted in the literature: "Complex adaptive systems show that surprising and innovative behaviors can emerge from the interaction of groups of agents, seemingly without the necessity of centralized control" [11].

Although having a positive result is desired, negative results could also occur (i.e., riots, war), but the focus for the current article is on positive emergence. Feedback is a key component to any system, open or closed, in that it supports learning within the system and aids in identifying new properties when emergence occurs. Having the ability to adapt and learn is one primary characteristic of a CAS [3].

Open systems operating in complexity are, by definition, non-linear. Changes within and external of the system affect all other parts of the system in unpredictable (non-linear) ways. These non-linear states of dis-equilibrium do not behave randomly either; they operate on the edge of chaos [11]. With too much order the system tends to revert toward the original state of equilibrium, while too little order causes the system to potentially reach its undesirable state of chaos [39]. Given the right amount of complexity, systems can self-organize [39] and find their optimal balance.

Waldrop provided seven conditions that must be present for CAS:

- A network of many agents acting in parallel.
- Control is highly dispersed.
- Coherent behavior in the system arising from competition and co-operation among the agents themselves.
- Many levels of organization, with agents at one level serving as the building blocks for agents as a higher level.
- Constant revising and rearranging of their building blocks as they gain experience.
- Constant testing of its implicit or explicit assumptions about the way things are out there.
- Exploitation of the many niches in the system by agents adapted to fill those niches [33].

These seven conditions [33] expand upon Holland's [2] original conception of the essential components of CAS: parallelism, competition, and recombination. Other literature identified the following four critical characteristics of CAS as being; nonlinearity, order emerges from interactions, irreversibility, and unpredictable outcomes [24]. These four characteristics are described below:

1. nonlinearity, that is small changes in the input or the initial state can lead to order of magnitude differences in the output or the final state
2. order emerges from complex interactions
3. irreversibility of system states, that is, that change is path dependent; and
4. unpredictability of system outcomes. [24]

4. Complex adaptive team system (CATS)

A leader facilitating the interactions that take place within and among CAS needs to begin at the individual level and work their way up to the organizational, industry, or network level, depending on the goal of the interaction or change initiative. This bottom-up approach is the desired approach when leading CAS. The following mechanisms are ways in which leadership can alter and support CAS. Leadership has the ability to alter:

- the size of the system and the number of sub-units within it (N),
- the interdependence among component units (K),
- the collective schema of members (P), and
- the interdependence of the system on others (C) [12].

Here, fostering and leading CAS is a function of the structure of the system, its interdependence, its collective cognitive structure, and its interdependence (f [N + K + P + C]). To facilitate the structure of a CAS the current research utilized Turner and Baker's [6] TELDE model. Within the TELDE model the systems components act interdependently (K), team members develop collective cognitive structures (P), while operating interdependently (C) to obtain the team's task. The size of the system and its sub-units (N), as identified by Hunt et al. [12], is a function of the number of TELDE models operating in succession. Collectively, the TELDE model along with the facilitating functions of [K + P + C] is presented in the following theoretical model as the Complex Adaptive Team System (CATS). The CATS model can be structured as a multi-team model or as a larger networking model, depending on the structure and the number of sub-units (TELDE models) in the CATS model. The CATS model provides a tool for organizations to recombine organizational resources, or to re-architect their business unit portfolios (40), when adapting to changing markets.

The following sections provide a review of Turner and Baker's [6] TELDE model and its components, presents interactions as a new level of analysis for the CATS model, identifies the different CATS levels, discusses the role that leadership plays in implementing CATS, and places the CATS model in context (OL/LO, Organizational Change, Collective Cognitive Structures, Innovation, Cross-Business-Unit Collaborations).

5. The team emergence leadership development and evaluation (TELDE) model

The Team Emergence Leadership Development and Evaluation Model (TELDE) provides a visual representation of leadership development that derives natural, organic, leadership growth and team learning [6]. Typically, teams are not structured in a way that allow each group member to share in the team's leadership role, provide feedback to other members during their leadership role, and reflect on their personal performance during their tenure as the team leader. While it is typical for team members to learn from other team members during teamwork (e.g., achieving the team's tasks), it is rare for team members to learn both individually and collectively during these teamwork episodes (e.g., transition from one task to the next). Teams have historically consisted of a single leader with members relying on the leader for direction and guidance, this traditional model is still widely used today [11]. The TELDE model presents an approach in which each team member, regardless of rank within the organization, acts as the team leader for one of the team's task-episodes (sub-task), ultimately resulting in all team members taking a leadership position while observing and providing feedback to other team members during their leadership tenure. This model provides the characteristic of "leadership development, team development, shared leadership, coaching, self-organizing and practice" [6], the characteristics of leadership development is also achieved by each team member by them taking a leadership role during one of the team's task-episodes.

The model, as shown in **Figure 1**, illustrates a four-member team performing a project with four task-episodes (one task, four subtasks). The tasks are shown on the X-axis with the team members on the y-axis. As team member one takes ownership of his/her task and begins to drive it to completion, they are building their own leadership skills, as well as displaying leadership traits and characteristics for the rest of the team. As the first task concludes and team member two is taking over for the next task, a phenomenon known as transference occurs, where team member two is applying and growing in their own leadership capabilities by applying what they learned from team member one, further adapting to their own task situation. This same pattern continues for team members three and four, each member learning from the previous leader's task achievement and eventually bringing the project to completion. At the height of each team member's development there is a point known as leadership emergence [6]. This is the peak of adaptation to the leadership role and the high point of application of their new skills that the team members experience in their time as task leader.

The TELDE model focused on leadership development at the individual level (team members) while addressing leadership as a group construct [6]. The TELDE model was presented as a model for organizational leadership development and leadership; however, this model has far-reaching potential in obtaining other organizational developmental objectives. This model could be implemented to achieve organizational change initiatives, to implement organizational culture

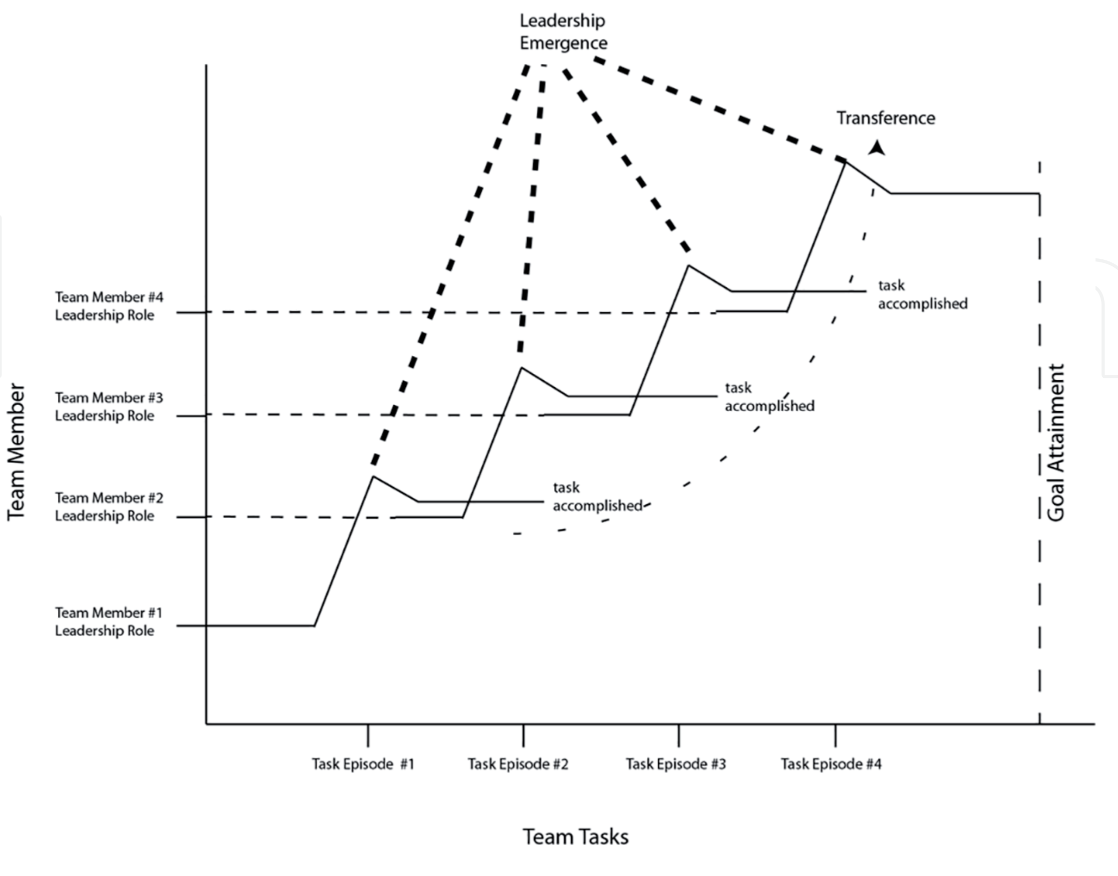

Figure 1.
The Team Emergence Leadership Development & Evaluation (TELDE) Model. Note: From Turner and Baker [63].

interventions, as a means of adopting a new organizational policy, to training or onboarding new employees. The TELDE model's utility is further expanded upon in the current research by incorporating it as the fundamental structure for the CATS model due to it being a CAS with individual agents working independently and interdependently toward a common goal while adapting and operating in a self-organizing manner toward emergence.

6. Interactions: level of analysis

Complex adaptive systems are non-linear by definition, with an unlimited number of ways to abstract its processes. Richardson [28] highlighted this point by stating:

> *Because of the nature of nonlinearity there is a huge number of ways to abstract a (nonlinear) problem in such a way that will easily be confirmed by our limited empirical evidence, i.e., there is one way to 'curve-fit' a linear problem (assuming a fixed number of dimensions) but there is an infinite number of ways to 'curve-fit' a non-linear problem.*

Richardson [28] continued by indicating that there is no one right abstraction or model when addressing non-linear models. Here, the only way to accurately model non-linear models, as in CAS, is to construct the CAS from the bottom up [28]. Rather than working backwards from some desired state of which we have limited knowledge [28], CAS should be addressed from what is known, the interactions that lead to complex patterns and emergence [12]. The function of leadership when operating in CAS is to foster and direct these interactions, leadership is inter-actional [4] through shared roles and responsibilities among the agents, resulting in a bottom-up process.

6.1 Complexity takes a connectionist perspective

The CATS model takes the connectionist perspective for viewing, understanding, and predicting CAS. The level of analysis does not take place at either the macro level (i.e., team, department, organization) or the micro level (individual). The level of analysis identified here is new; it views the interactions between two independent agents within a system as a level of analysis worth considering. This dyadic event becomes the beginning of the overall process that leads toward emergence; thus, it should be considered as a means of better identifying and representing this process. The current article defines interactions as "the network of linkages across which information flows and connects" [14]. While the rules of engagement among individual agents in a system are critical factors of emergence in that individuals act to form these interactions, the individual and the interaction are considered two separate levels of analysis. The CATS model presents a theoretical model that provides an approach to understanding and guiding CAS. This theoretical model concentrates on the outcome that results from these interactions moving toward emergence rather than on the rules-based approach trying to understand the rules of engagement that led to these interactions.

This interaction level is believed to be the driving factor that fosters emergence that takes place in, and spans across, all levels, rather than the levels driving interaction. This interaction level is where leadership should focus a large portion of their efforts toward when operating in CAS. Concerning CAS, and more importantly to the CATS model, interactions that begin at the individual level within the TELDE model hold the potential to emerge into larger organizational, and even global, patterns.

6.2 CATS levels

As identified, it is the interaction between the agents of CATS that result in individual learning, the formation of new cognitive structures that contribute to emergent properties. Also, interactions among CATS produce much needed emergent properties; organizational learning and learning organization properties that allow organizations to better address wicked problems and to operate in today's complex globalized environment. In viewing the level of analysis as the interaction, we identified four different CATS interaction levels: one to one/dyad, dyad to many/team, team to team/organization, and organization to network/industry. **Figure 2** identifies each of these interaction levels.

Each of these four interaction levels consist of variations on micro- and macro-level perspectives. Micro-level represents the lower or smaller entity when compared to a higher or larger, macro entity. These micro- and macro-levels are utilized when representing multilevel models or theories. When a higher level affects a lower level, for example when new governmental regulations affect organizational policies, this process is identified as being top-down. Likewise, when a lower level affects a higher level as in poor employee engagement affecting organizational performance, this is identified as being a bottom-up process. Kozlowski and Klein [41] identified top-down processes as macro-levels exerting influence over micro-levels. Alternatively, bottom-up processes were defined as higher emergent properties that originated at lower levels [41]. In sum, top-down processes provide influence (e.g., mission statement, vision) while bottom-up processes have the potential of producing emergent properties. Because emergent properties come from bottom-up processes, and these processes are driven by the interactions among the agents involved, the focal point when addressing interactions as the level of analysis should be at bottom-up processes. However, even though the interactions and emergence come from bottom-up processes, the influence from the macro-level onto the micro-level (top-down) should not be disregarded. Both the bottom-up and the

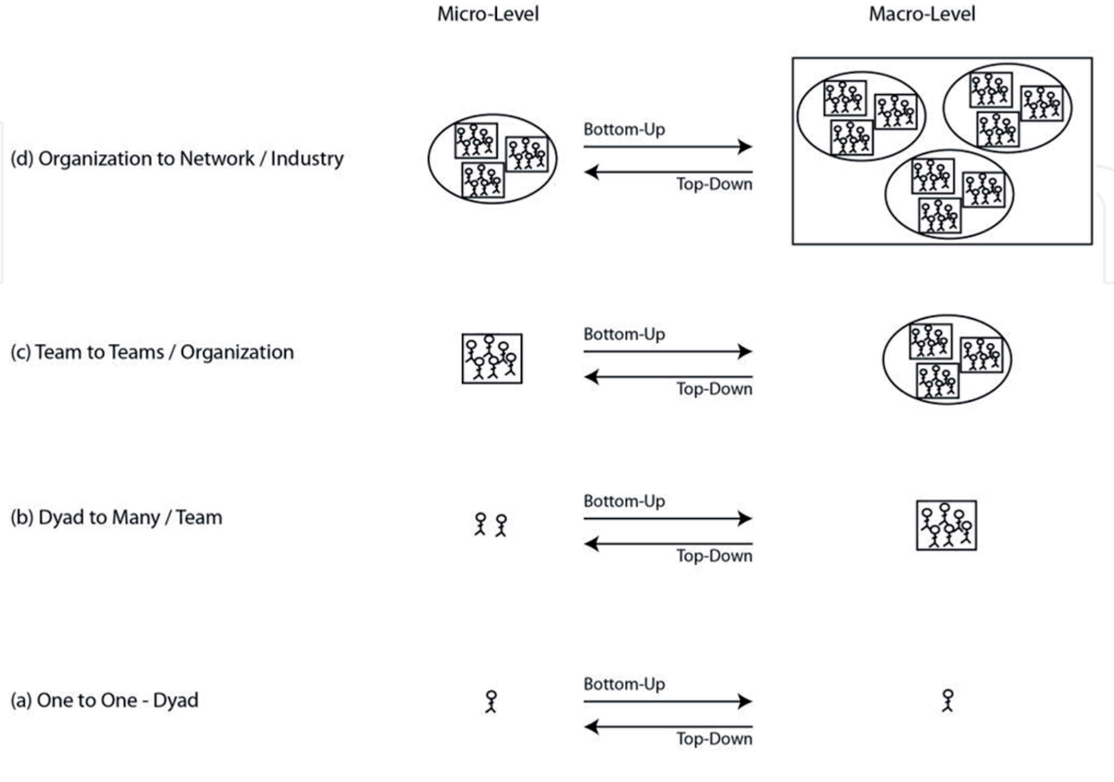

Figure 2.
Reciprocal Interactions at Various Organizational Levels.

top-down processes should be considered in totality. This is depicted in **Figure 2** by the arrows, an arrow from a micro-level to a macro-level represent emergent, bottom-up, processes. Likewise, an arrow from a macro-level to a micro-level represents influential, top-down, processes.

These levels of interaction are similar to the enabling functions identified by Uhl-Bien and Marion [15]. Their enabling functions began at the micro level (individual level) and aggregate into macro levels which, in turn, also affect the messo level. **Figure 3** provides a representation of how these different interactions would take place within a single organization, inter-organizationally. In **Figure 3**, interactions take place at the individual level within each TELDE model, intra-team. Also, with multiple TELDE models operating sequentially (the CATS model) interactions take place across each team, inter-team to represent the macro-level.

In the inter-organizational model (**Figure 3**), each system (TELDE model) has peripheral influence over other, adjacent, systems. Here modularity is present as identified by [36].

The aggregate of the micro- and macro-level interactions, along with replication of the CATS model in additional organizations or entities, represents the messo-level interactions. These messo-level interactions are best represented in **Figure 4** in which the CATS model is replicated, resulting in interactions inter-organizationally or across different networks (messo-level interactions). He et al. [42] provided one example of this when the researchers looked at how industrial clusters (CAS) formed, they formed through the interactions of the micro-organizations: "clusters form from micro-interactions and spontaneously evolve over time without any intervention". These micro-interactions emerged across the micro-organizations

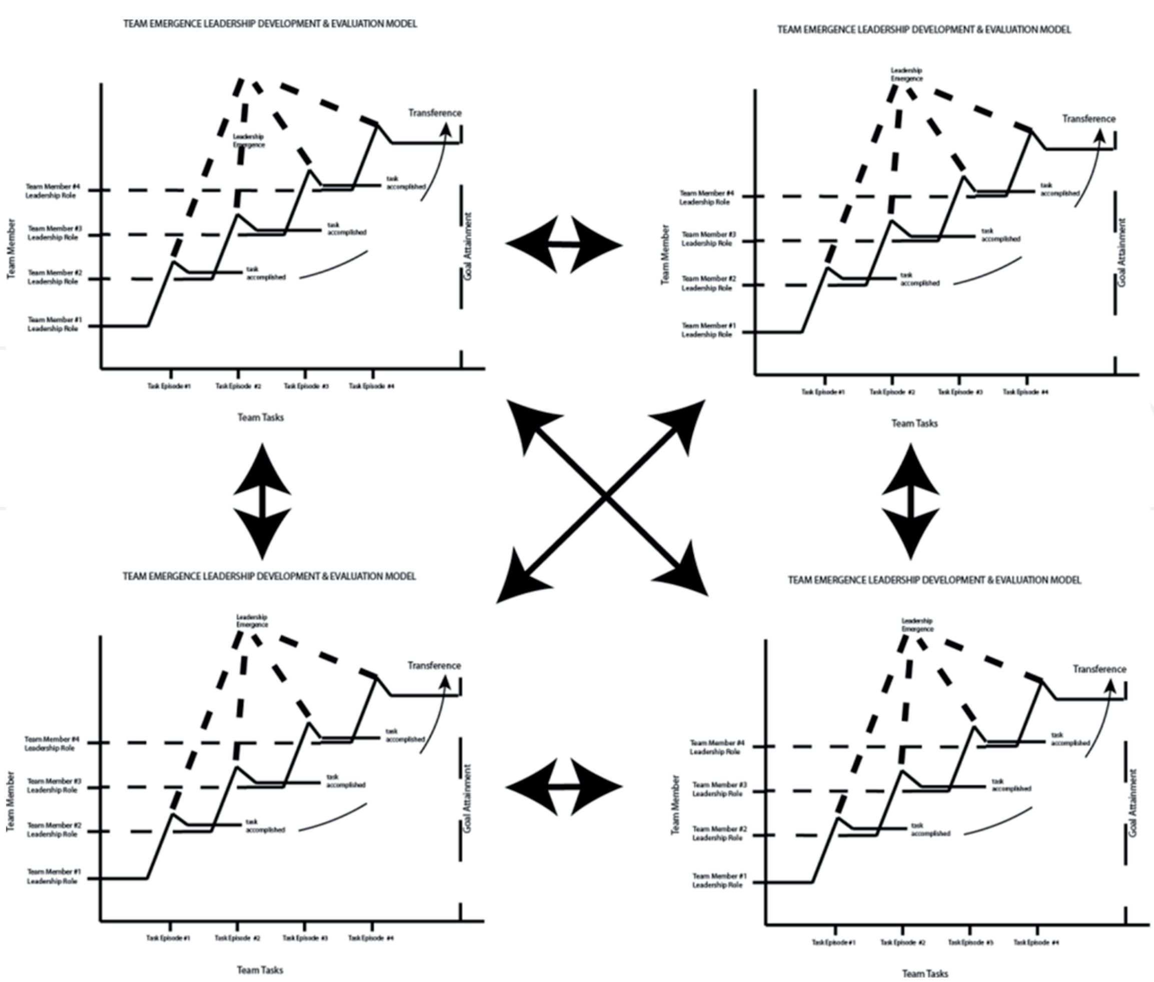

Figure 3.
CATS Model: Multiple TELDE Models Acting Inter-Organizationally.

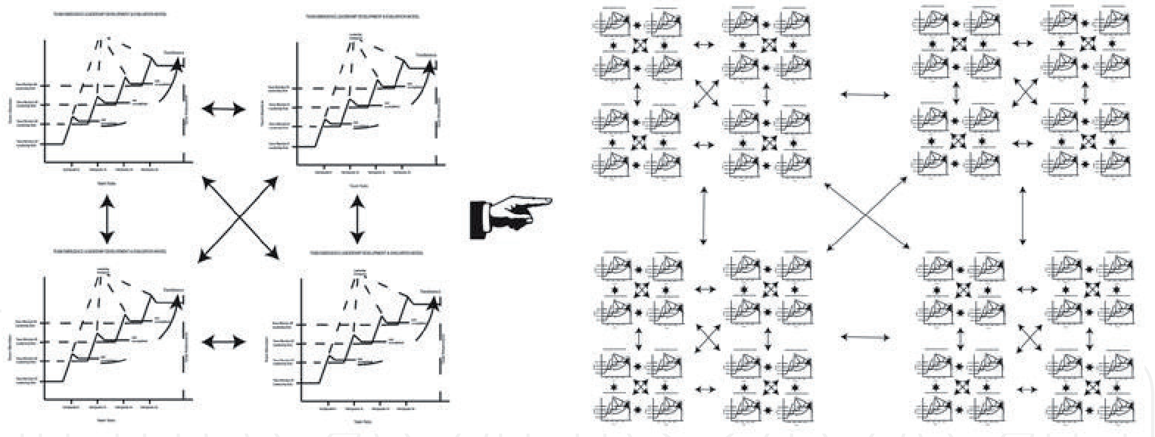

Figure 4.
CATS Model Intra-Organizationally or Across Networks (Globally).

and eventually influenced the formation of industrial clusters. In essence it is the initial dynamics that evolve into an organization's adaptability [15], this set of interactive dynamics should be facilitated, not managed, by utilizing the CATS model.

7. The role of leadership

The best way to manage CATS is to promote and flourish the interactions that take place within and between TELDE systems. Luoma [43] stressed that managers must be capable of leading in times of rapid change. Managements' role within complex systems expands beyond traditional human relation functions to one that manages systems and networks [44]. Facilitating these interactions and acting as a change agent within such systems is another function of management. However, this function can only guide emergent processes and cannot control it due to its non-linear and non-predictable nature. A successful agent succeeds by triggering change to meet its own systemic needs [33]. Bovaird [33] identified this process as a *self-reinforcing spiral*, operating similar to how the knowledge management literature [45–47] described *knowledge creating spirals* and how He et al. [42] described *knowledge spillover*. Even if attempts to manage the emergence is taken, causal mechanisms remain unknown due to the complexity and number of interactions that cannot be accounted for. This is similar to punctuated equilibrium in which some causes are weakly associated to certain effects, but not all effects have associated or knowable causes [33].

Organizations and systems are unable to remain in a state of equilibrium, successful organizations and systems avoid equilibrium [33] in favor of operating on the edge of chaos. Organizations should, due to this *run toward chaos*, build structures and systems that expedite self-transformation and create conditions for change that lead to self-organizing systems [33]. Granted, however, even though it may seem that self-organizing systems come free to organizations in which they do not need to be managed, this thinking is counter-intuitive. Lindberg and Schneider [20] identified that order is not free when talking about self-organizing systems. Instead, leadership must be able to achieve the right balance between equilibrium and chaos without hampering the emergent processes that come from self-organizing systems [20]. Luoma [43] warned against efforts that try to eliminate this disorder, by eliminating this run toward chaos leaders can destroy the system's self-organizing capabilities. Here leadership plays a critical role in the self-organizing function [20], facilitating interactions with the system [48].

Organizations need to view leadership as an emerging construct that facilitates self-organizing behavior to achieve desirable outcomes [20]. Leadership also needs to take a more integrated approach that accounts for both inter-system (e.g., inter-team, inter-organization, inter-network) and intra-system (e.g., intra-team, intra-organization, intra-network) dynamics [49]. Tong and Arvey [44] identified three managerial behaviors for leading in complexity; enabling, sensmaking, and facilitating shared leadership. Enabling behaviors allow leaders to enable adaptive outcomes rather than control them, sensmaking relates to a leader's ability to identify what information is important and where a team's attention needs to be focused, and facilitating shared leadership involves collective leadership compared to one overarching leader [44]. The CATS model enables members to adapt as needed, allowing the system to emerge in response to internal and external environmental forces. Sensemaking results in the collection of individual accounts [44], which is inherent in the CATS model. The CATS model provides the collective leadership needed in that it views the team as the leader in the TELDE model [6].

This transformation to a new leadership is in alignment with the *Law of Requisite Complexity* [14, 50]: "It takes complexity to defeat complexity—a system must possess complexity equal to that of its environment in order to function effectively" [14]. He et al. [42] explained that complexity requires a great deal of abstraction to predict general patterns of change. The CATS model aids this new leadership in facilitating and managing this complexity.

8. CATS model in context

8.1 Organizational learning, learning organization

Antonacopoulou and Chiva [17] identified social complexity to highlight the need for learning in OL processes. They highlighted learning as being central to complexity because learning highlights the conditions of, and the outcomes from, interactions that fosters self-organizing activities which lead to emergence. Mowles [26] introduced this process as *learning through* complexity. Boal and Schultz [11] described learning in complex systems as being related to information flow within these social systems, driven by the interaction patterns of the agents within the system and the interaction patterns between systems. Learning is a process that cannot be controlled when identified as a dynamic and complex process [17]. Learning in complex systems is a product of the connections and interactions of the individual agents that result, or contribute to, emergence. At the more macro level, learning is a product of the connections through interactions across systems, such is the case in OL practices when learning occurs in cross-functional groups. This learning through systemic interactions is an area that needs to be further developed and researched through different organizational settings to determine if fostering interactions at various levels result in emergence, thus mediating OL/LO or organizational performance.

8.2 Organizational change

Organizational change is often delayed due to four primary processes: structural, institutional, political, and learning processes [51]. The CATS model provides a model that potentially addresses all four delayed processes. The CATS model provides a structural model (structure) for driving organizational change as a bottom-up, self-organizing, process (learning) while achieving organizational and stakeholder objectives (institutional) in response to any environmental forces from the community, the government, or due to globalization (political).

Organizational change has been identified as occurring in cascades where change leads to additional change which, in turn, leads to even more change [51]. Here cascades occur within each TELDE model, ultimately resulting in organizational change through the aggregate from the CATS model.

At the network level, as shown in **Figure 4**, community ecology looks at the interdependence among differing organizations in which an organization's legitimacy is related to its similarity and proximity to already legitimate organizations [52]. This network model, supported by the CATS model, provides a platform for collectives to structure similar cognitive spaces. This network model is representative of organizational interdependence models in that it provides interdependence between systems while also providing a proximate association. Organizational interdependence occurs at all levels of analysis; networks, populations, communities, global [52]. In addition to providing a model for organizational interdependence, identifying the interaction as the level of analysis for these network systems aid organizations, communities, and governments with a new architecture to facilitate global change. Further research is needed to test the CATS model to determine its impact on organizational change and organizational interdependence.

8.3 Collective cognitive structures

Learning within dynamic and complex systems, agents have the capability of being emergent and transformative [53], similar to the concept of transference in Turner and Baker's [6] TELDE model. Through observation, practice, feedback, and reflection individual agents learn individually as well as collectively. This process was described by Boal and Schultz [11] as shared schemas where interactions lead to the development of similar cognitive structures or schemas. Likewise, Borzillo and Kaminska-Labbe [10] contrasted individual intelligence (interconnected neurons) with collective corporate intelligence (interconnectedness among agents). Turner et al. [54] identified similar team or group cognition models that explain how information is structured and processed collectively: shared mental models, SMM [55]; team mental models, TMM [56, 57]; information sharing, IS [58] transitive memory systems, TMS [59]; cognitive consensus, [60]; and group learning, [61, 62]. Using complexity science to understand corporate entrepreneurship strategy, Crawford and Kreiser [21] identified two organizational antecedents: "the *cognitions of the individuals within the focal firm* and the firm's *external environmental conditions*" (emphasis in original). The shared cognition among the agents within the CATS aids in their capability of becoming more adaptable. At this point, learning becomes collective and emergence begins to develop. Further research is needed to determine the impact that the CATS model might have on shared cognition in teams and small groups, as well as assessing its influence on small networks.

8.4 Innovation

Chiva et al. [30] associated OL with competitive issues such as innovation. They identified innovation as involving new organizational processes along with more traditional concepts: new products, new services, and new knowledge [30]. Innovation is presented as being a collective construct, requiring the organization to learn and to develop new knowledge for the innovative product or process while, at the same time, learn from the innovative processes through feedback channels [30]. This reciprocal process includes both bottom-up and top-down processes at the same time. The CATS model needs to be tested to determine its impact on organizational innovation. The CATS model is one tool that could be utilized to manage innovative processes within organizations, providing self-organizing systems to be innovative (bottom-up) while addressing organizational problems (top-down).

8.5 Cross-business-unit collaborations

Martin and Eisenhardt [40] introduced restructuring as one method for organizations to address changes in the market. One such effort is in cross-business-unit collaborations. Unfortunately, there is a lack of theoretical models and research addressing "how executives create high-performing cross-BU collaborations" [40]. Their research showed that executive decision-making was effective in multi-business settings when executives were part of a multibusiness team, acting collectively while consensually agreeing to decisions. These multibusiness teams act in a manner that is consistent with the TELDE model which could foster future research efforts. When these multibusiness teams operate across different businesses or industries, they act similarly to the CATS model. The CATS theory adds to the multibusiness organization literature by including a model that incorporates complexity theory and complex adaptive systems. Thus, making a fundamental contribution and meeting the requirements of a new theory [40].

9. Summary

The Columbia response effort began as "idiosyncratic local organizing actions" [29] among the participating agencies (i.e., NASA, FEMA, DOD, EPA). In order to respond quickly and to organize efforts between the multiple agencies that became involved, Beck and Plowman [29] identified four main categories that led to the successful collaborative efforts that came from the initial chaos:

1. Initial contextual conditions precipitated the collaborative effort.

2. The organizing actions taken by independent agencies.

3. The development of trust.

4. The development of a collective identity.

Success from the Columbia response effort resulted, not from any one agency being in charge, but from the in-charge agency (FEMA) acting as an enabler for the other agencies [29]. Their case study exemplified the support function from the host organization as a means for self-organization to take place. This support function included providing guidance, resources, and tools to the team/group as needed so they could complete their tasks. Also, the interactions that took place within the CAS were facilitated by the host organization. By providing the right direction and resources, the team/group could focus more attention on self-organizing activities aimed toward goal attainment, and in some cases, emergence. The agents involved in the Columbia response effort practiced an aggregated form of the CATS model in which agents acted interdependently toward one common goal that was facilitated by FEMA.

Complexity theory takes a different perspective when viewing systems. Rather than examining systems using reductionistic methods, complexity takes a connectionist perspective in understanding that emerging properties arise from the interactions among and between the system's elements. As systems evolve from being complicated to being complex, typically by increases in the number of components and interactions within a system, CAS are formed requiring leadership to be distributed. Linearity is often associated with models that provide predictability and causal relationships [43] while CAS are associated with non-linearity, open systems, and non-predictablility. One method of facilitating and managing CAS is through the implementation of Turner and Baker's [6] TELDE model. A CAS that utilizes the TELDE model as a means of driving change is known as the CATS model.

Micro-level activity and interactions aggregate, and eventually reflect higher-level activities [21]. This results in organizational outcomes being the result of micro-level adaptive and emergent forces through CAS and CATS. Crawford and Kreiser [21] explained: "Unless a new activity pattern emerges or is imposed by top-down tensions, the higher level aggregate activity will *exactly* [emphasis added] reflect and resemble the scaling pattern of the micro-level pattern". When viewing CAS, Boal and Schultz [11] stressed that leaders must create the structures and interactions that occur in CAS, allowing them to self-organize and emerge, as in the CATS model presented in this chapter. It was also stressed that strategic leaders should be the catalyst for adaptive systems [11]. Uhl-Bien et al. [14] presented the concept of *enabling leadership* for their complex leadership theory in which leadership should concentrate their efforts to foster interactions and interdependency while injecting adaptive tension. Campbell-Hunt [19] acknowledged that leaders should be a participant in the flow of events that take place in CAS/CATS as opposed to just trying to control the flow of events. Leaders should make available organizational resources while releasing control of the CAS/CATS in order to allow the system to self-organize and emerge into a new order [19]. This active participation on the part of leadership was identified by Campbell-Hunt [19] as being "an epistemology of engagement with the challenge of an unknowable emergent order" and is presented here in the CATS model.

Chiva et al. [30] presented innovation as introducing either new products, processes, markets, or organizational innovations. Organizational innovation involves incorporating new organizational methods, such as in implementing the TELDE model as the foundation of building CATS to drive organizational initiatives such as leadership development, new employee orientation, change initiatives, diversity training, organizational culture exercises, and new technology orientation, to only name a few. Today's new leadership is best identified as being capable of influencing systems [12]. This influence comes, in part, through leaders' managing the interactions between teams and agents as depicted in the CATS model. Leaders' focusing on these interactions result in building connections and connecting agents, providing a new direction for leaders in today's complexity: "What might get lost in leadership in the flow of practice is the basic connection (relationships) between the organizational agents" [4]. Utilizing and implementing CATS as standard practice to drive knowledge creation and innovation, and in making new connections within organizations, is one tool that is available for today's leaders to operate in today's complex and challenging environment.

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