Complexity Theories: Perspectives for the Social Construction of Organizational Transformation

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Traditional approaches to the study of organizational change and transformation, and the processes by which they develop new structural frameworks, are considered by some to be limited and potentially inadequate in guiding effective research and applied management practice (Mathews, White & Long, 1999; Van de Ven & Poole, 1995). Yet the challenges organizations must face to sustain themselves in an ever-changing environment continue to expand in order of magnitude and complexity.

The collective theories of complexity and chaos, emerging from the scientific domains of quantum physics, theoretical biology, chemistry, and ecology (Kauffman, 1995; Mandelbrot, 1987; Prigogine, 1996; Maturana & Varela, 1987), offer new perspectives from which to explore sustainable organizational change and transformation. Complexity science is an interdisciplinary field of study that embraces a wide variety of approaches, yielding, at present, no single unified and coherent theory (Cohen, 1999). However, complementary elements of the theories originating in the physical and biological sciences have far-reaching implications for the development of knowledge (Lewin, 1992).

Social scientists have begun to explore the degree to which complexity theories offer useful perspectives for understanding complex human systems (Cohen,1999; Gregerson & Sailer, 1993; Lewin, 1992; Mathews, et al 1999; Stacey, 1996; Warren, Franklin & Streeter, 1998). The application of complexity perspectives in the study of social systems has particular relevance in the areas of organizational development and transformational change. What can we learn from complexity science about how organizations develop and transform? How might elements of the complexity theories contribute to the development of a framework from which transformational change can be socially constructed?

This paper provides a conceptual overview of key complexity theories and examples of the ways in which social scientists have drawn on these theories to understand organizational change and transformation in human systems. Few studies were found which link perspectives of complexity science with social constructionism and transformational change, thus suggesting that further study will be required to systematically bring together relevant perspectives needed to develop a framework for organizational transformation based upon these integrated concepts.

An Emerging Paradigm

Numerous theories have emerged in the past two decades from the physical and biological sciences that, taken together, suggest a dramatic paradigm shift viewed by some to be an integral part of a cultural transformation that impacts the larger social arena (Lewin, 1992; Prigogine, 1996). The view of the universe as a mechanical system that can be analyzed, predicted and controlled is being replaced by a holistic worldview in which the integrated whole is emphasized over the disassociated collection of parts (Capra, 1996; Gleick, 1987; Kauffman, 1995; Lewin, 1992).

The evolving holistic paradigm requires an expanded view of values and cognition characterized as tendencies toward objective assertion on one hand, and subjective integration on the other. Objective assertion reflects the tendency to establish elements of certainty in order to describe social reality from a position of individual independence. Subjective integration advocates the tendency to collaboratively generate knowledge in context and co-create social reality from a position of synergistic interdependence. The holistic paradigm suggests the need for both (Capra, 1996).

The table below describes the characteristics of an expanded paradigm that makes room for the paradoxical elements of *both* objective assertion *and* subjective integration needed to make sense of a complex world.

Table 1
Expanded Paradigm of Cognition and Values

Cognition		Values	
Assertive	***Integrative***	***Assertive***	***Integrated***
Rational	Intuitive	Expansion	Conservation
Analysis	Synthesis	Competition	Cooperation
Reductionist	Holistic	Quantity	Quality
Linear	Nonlinear	Domination	Partnership

Adapted from Capra, 1996, p. 10

Among social scientists using the lens of complexity science for exploration and development of theoretical models, there are voices using a similar language, reflecting fundamentally different paradigms (Griffin, Shaw & Stacey, 1998). Objective voices tend to speak of systems as pre-given external realities in which the observer stands outside in order to describe the dynamics. These voices tend to emphasize the degree to which new methods of analysis found in the complexity simulation and modeling tools can assist in the prediction of causal linkages within a complex system (Cohen, 1999; Guastello, 1995). Intersubjective or relational voices tend to reflect interaction with subjects within a system in the co-evolution of a jointly constructed social reality. These voices tend to emphasize emergent and unpredictable aspects of self-organizational processes and the creative potential within complex systems (Goldstein, 1995).

There are indeed diverse points of view reflected in the literature about whether or not, and if so, how, theories from complexity science are useful for studying human systems. However, a growing contingent of theorists are committed to the development of rigorous models—both empirical and qualitative—that will offer fundamentally new ways to conceptualize complex human systems (Dooley & Van de Ven, 1999; Guastello, 1995; Lissack, 1997; Stacey, 1996).

Complexity theories have emerged in the language of the new mathematics, one of relationships and patterns. The new mathematics is qualitative rather than quantitative and thus embodies the shift of emphasis from objects to relationships, from quantity to quality, from substance to pattern (Capra, 1996; Lewin; 1992). Only in recent years have new mathematical tools and high-speed computers allowed scientists to model the nonlinear and interconnected characteristics of networks. The result is an emerging coherent mathematical framework for understanding complexity (Gregersen & Sailer, 1993; Gleick, 1987). Mathematical theories themselves are *not* theories of physical phenomena but rather theories which embody concepts and techniques that are applied to a broad range of complex phenomena (Kauffman, 1995).

Systems Theories

Complexity theories are about the study of nonlinear dynamical systems (Goldstein, 1994). Systems theories have long guided approaches to the study of physical, biological and social phenomena. Ludwig von Bertalanffy's *General Systems Theory,* introduced in the 1950s, explained relationships of parts to the whole as a dynamic interchange of energy, force and information. A system can be fully understood only by analyzing its parts in the context of the whole, when attention is shifted from *objects* to the *networks of relationships* among objects (Hatch, 1997).

Inherent in the evolving models of systems theories are the concepts of *linearity* and *nonlinearity*. In linear systems, interaction is based on one-way causality; outcomes are predictable and equilibrium conditions remain steady. In nonlinear systems, interaction is multidirectional, outcomes are unpredictable, and far-from-equilibrium conditions can undergo structural transformation. *Dynamical* systems are nonlinear systems that change, but from which changes in outcomes appear to bear no relationship to the changes in system input (Lewin, 1992).

Norbert Wiener and others in the field of *cybernetics* developed models for understanding the system characteristics of *feedback* and *self-regulation*. Feedback is information that enables the system to adjust by changing inputs and processes needed to achieve required outputs. The cyberneticists distinguished between two kinds of feedback—self-balancing (or *negative*) and self-reinforcing (or *positive*) feedback. Negative feedback holds a system within pre-specified boundaries; examples of negative feedback mechanisms include thermostats and budgets (Briggs & Peat, 1989; Capra, 1996).

Positive feedback is the amplification and iteration of information, which means that the output of the system is fed back into the system at the start of its next action. Systems require positive feedback to change; however, positive feedback can create tension, instability and unpredictability. Energy coming into the system as a result of positive feedback creates system instability, which can lead to one or a series of *bifurcations*. Bifurcation points mark sudden changes in a system's structure, in which the system will either disintegrate or reorganize into a new form capable of resolving the tension and utilizing the increased flow of energy that results from amplified feedback (Goldstein, 1994). The co-existence of negative and positive feedback cycles provides parameters required for self-regulation of the system.

Social scientists Bateson (1972) and Mead explored of the dynamics of circular feedback processes in social systems. The reflective and recursive nature of human feedback led them to develop a model of *second-order cybernetics*, which has contributed to metalevel theories of cognition used in understanding complex, nonlinear, dynamical human systems (Warren, et al, 1998). Neurobiologists, Maturana and Varela, have developed an expanded theory of cognition, also drawn from principles of cybernetics, which is described in a later section of this paper.

Mathematical Chaos

Mathematical chaos is a cornerstone of complexity science. It is an empirical model that describes the dynamical qualities of a nonlinear system with precision and accuracy. Changes within a nonlinear system are marked over time by a series of phases, each of which is governed by an *attractor*. An attractor is a pattern of behavior into which a system settles. Each phase has its own uniquely characteristic sets of behaviors, which exist in latent form in the original nonlinear configuration of the system. As nonlinear systems pass through far-from-equilibrium conditions, the various attractor potentials are released. There are three types of attractors: stable equilibrium attractors, unstable disequilibrium attractors, and strange or chaotic attractors (Kauffman, 1996, Lewin, 1992; Thietart & Forgues, 1995).

Stable attractors are linear trajectories (movements through space) of behaviors drawn to a single point or a simple periodic cycle; for example, the pendulum swing of a clock. The potential or archetypal behavior within a simple attractor is regular and predicable. Deterministic nonlinear feedback systems are attracted to stable equilibrium when *control parameters* are low; that is, when information or energy is disseminated slowly throughout the system. The control parameter, or negative feedback loop, damps down any disturbances to the system, thus compelling behavior to remain at a steady state of equilibrium (Briggs & Peat, 1989).

Unstable attractors are nonlinear trajectories drawn to random cycles of behavior. The potential or archetypal behaviors within a complex attractor are irregular and unpredictable. Control parameters may be set at very high levels as a result of positive feedback that exponentially amplifies small disturbances to the system, thus creating information or energy coursing through the system at a very rapid rate. The unstable pattern of behavior increases in intensity, cycling out of control toward infinity, until it is brought to an explosive halt by some external constraint—ultimately leading to disintegration.

Strange attractors are synonymous with the term *mathematical chaos*. Strange, or chaotic, attractors are nonlinear trajectories drawn into irregular, seemingly random cycles of behavior. Control parameters are opened up through increased information or energy flow, thus generating increasingly complex behavior. All nearby trajectories are drawn into its orbit, yet no two orbits overlap. The trajectories separate because of the property of *sensitive dependence on initial conditions,* which means that small changes may be escalated into major differences in behavior. The strange attractor literally “attracts” or pulls the broad range of behaviors into an order that emerges from the within the randomness of behavior, patterns of behaviors that organize themselves within defined boundaries (Kauffman, 1995). As a system generates ever-increasing complexity through the chaotic cycles of behavior, it continually bifurcates until it reaches the strange attractor state. Just before it does so, it may pass through a *phase transition* in which order coexists with chaos. This phase transition is described in the literature as the *edge of chaos* (Kauffman, 1995; Theitart & Forgues, 1995).

An example of a strange attractor frequently described in the literature is Lorenz's famous butterfly attractor. He discovered the chaotic model of the weather system quite by accident during the execution of a computer modeling simulation using an iterative mathematical formula. In restarting an experiment which was inadvertently interrupted, Lorenz unintentionally modified the rules of the mathematical formula ever so slightly, by carrying out the number used in the mathematical formula three decimal places instead of the original six. Within minutes of iterative calculation, the model produced a chaotic, patterned image reflecting a form of bounded instability, completely different that the original image (Gleick, 1987).

Lorenz discovered that, while the weather system is bounded or constrained by an order inherent in the system—for example, heat waves do not occur in the Arctic, nor do snowstorms occur at the Equator—the specific state of the weather is unpredictable and can be significantly impacted by tiny, chance changes. The constraining characteristics of the boundary and shape of trajectory movements provide the system with order and stability while the unpredictable aspects of their specific orbits introduce instability or disorder. As a result, the system's "choices" are no longer limited to a selection from a small number of equilibrium behaviors; instead, the range of choices within the boundaries and shape of the attractor is now infinite (Briggs & Peat, 1989; Capra, 1996; Stacey, 1996).

The strange attractor is a potential pattern or archetype that has general qualitative features of stability—boundaries and shape. However, the actualization of the potential pattern is unpredictable, depending on the unique experience of the system over time. The chaos archetype is an irregular or potential fractal pattern (described in the next section) that emerges when the system flips autonomously between negative and positive feedback, thereby providing its own internal constraint (Lewin, 1992; Stacey, 1996).

Complex systems, whether physical, chemical, biological or social, are creative—able to "learn" in complex ways and shift to new structures—*only* when they operate at the edge of system disintegration, in a kind a phase transition between a stable zone of operation and an unstable zone of disordered regime, referred to as chaos. Neither the creative process itself, nor the outcome, can be planned or predicted at the edge of chaos. The links between antecedent and consequent conditions are not predictable nor are they controllable. However, the consequent effects are not necessarily random and chaotic because of an inherent order that emerges at the edge of chaos. This order does not occur according to a "blueprint" or prior determination; instead, it is created out of the chaotic conditions themselves. Mathematical chaos is indeed "an archetype of novelty, creativity, innovation, and surprise" (Stacey, 1996, p. 60).

Fractal Geometry

Concurrent with the development of mathematical chaos theory in the 1960s and 1970s, a new *fractal geometry* emerged independently as a result of Mandelbrot's work at IBM research laboratories. Fractal geometry describes the complexity of the irregular shapes in the natural world through a set of simple equations that combine to form infinite diversity. The most striking property of fractal shapes is that their characteristic patterns are found repeatedly at descending scales of subsystems throughout a complex system, so that their parts, at any scale, are similar in shape to the whole. Mandelbrot illustrates this property of self-similarity by breaking off a piece of a cauliflower and noticing that it replicates itself, the small piece approximating a small head of cauliflower (Capra, 1996; Mandelbrot, 1983). There are many examples of self-similarity in nature; however, before Mandelbrot's work, there had not been a mathematical language to describe it.

Strange attractors are examples of fractals (Thietart & Forgues, 1995). If parts of their structure are magnified, they reveal a multilayered substructure in which the same patterns are repeated continually. The theory of fractal geometry helps to conceptualize the shift from quantitative to qualitative descriptions of systems. While it is impossible to predict the values of the variables of a chaotic system at a particular time, it is possible to predict the qualitative features of the systems' behaviors through the mapping of fractal patterns. Social scientists investigating the presence of fractals in human systems note that in fractal organizations, similar behaviors and configurations are potentially observable at each organizational level (Thietart & Forgues, 1995). A fractal perspective also informs the study of cross-level relationships among individual, group, and organizational level learning (Morel and Ramanujam, 1999).

Chaos theory demonstrates how systems can derive complicated, unpredictable behavior from a small number of simple rules within fixed schemas common to all components of the system. Fractal geometry identifies organized patterns of behavior that reflect qualitative characteristics, which replicate themselves throughout the system. The theory of *dissipative structures*, described in the next section, reveals how systems use disorder to generate new order through the process of spontaneous self-organization.

Dissipative Structures

The second law of thermodynamics explains that, over time, *entropy* will irreversibly increase the amount of disorder in a system, ultimately leading to disintegration (Progogine, 1996). However, the general course of biological, psychological and cultural development has been in the direction of *negentropy*—an increasing level of order and complexity within a system (Katz & Kahn, 1966). In an attempt to resolve this paradox, Russian chemist and Nobel Laureate, Ilya Prigogine, suggested redefining the field of inquiry needed to describe open systems in *far-from-equilibrium* conditions undergoing irreversible transformations (Prigogine,1996; Stacey, 1996).

Prigogine learned that if a particular liquid is heated in particular ways, it will reach a critical point of instability far from equilibrium in which highly organized patterns emerge, thus revealing the system's capability for self-organization (Goldstein, 1994). A liquid is at thermodynamic equilibrium (heat flux) when the temperature is uniform throughout and it is closed to its environment; the molecules are in random position independent of each other, with no correlation, patterns or connections. When a control parameter, heat, is turned up, the liquid is pushed far from equilibrium through a positive feedback process, which amplifies small fluctuations throughout the system. After a time, a critical temperature is reached, resulting in a bifurcation (series of bifurcations), and a new structure (heat convention) emerges through the self-organization of the molecules; molecular movements are correlated with each other as though they are communicating, thus establishing a degree of connectivity. However, the particular direction of each cell's movement is unpredictable (Jantch, 1980; Prigogene, 1996).

Movement from a situation of perfect equilibrium to one of greater complexity occurs through a destabilization process, not unlike mathematical, deterministic chaos (Lewin, 1992). The system is being pushed away from stable equilibrium (which takes the form of a stable attractor) through a series of bifurcation points toward a strange or chaotic attractor. The dissipative process illustrated in the Prigogine's experiments exemplifies the need for destruction of the old structure as it makes way for the creation of a new (Stacey, 1996; Goldstein, 1994).

When a system is at equilibrium, its nonlinear creative potential does not reveal itself; the observable linear processes are sufficient for system functionality. Under far-from-equilibrium conditions created by "heat," the inherent, nonlinear potentiality emerges as the system reorganizes itself into a more complex structure (Goldstein, 1994).

Prigogine's dissipative system exemplifies one of many paradoxes found in nature: equilibrium, in the form of symmetry and uniformity of the pattern, is lost, but a form of structure, albeit modified, is retained. D*issipation* reflects chaos; and *structure* implies order. The simultaneous interaction of the two in far-from-equilibrium conditions led Prigogine to refer to the phenomenon as *dissipative structure*. A dissipative structure is not just a result, but a self-organizing process that uses disorder in order to change (Prigogine, 1996).

So far, this paper has described theories *of mathematical chaos*, *fractal geometry*, and *dissipative structures.* These theories were developed in the context of *deterministic* (nonliving) nonlinear feedback systems; that is, networks with a few simple and absolute rules fixed over time that apply to all agents without exception, and which are not focused on achieving a purpose. The study of deterministic systems reveals fundamental elements valuable for the study of the more complex, adaptive, human systems.

Self Organization, Autopoiesis and Cognition

The emerging self-organizing patterns characteristic of dissipative structures suggest a radically different view about how complex human systems function (Prigogine, 1996). The changes that occurred in Prigogine's experiments did not occur as a result of a hierarchically imposed mandate. Instead, the change was self-organized, self-bounded, self-generated, self-guided and self-perpetuating as the system reconfigured its own resources in the face of a far-from-equilibrium challenge, heat, created through interaction with the environment (Goldstein, 1994; Jantch, 1980; Prigogine, 1996).

Neurobiologists, Maturana and Varela (1980, 1987) developed the theory of self-organization in the context of living systems. They coined the term a*utopoiesis* to describe the general *patterns* of organization common to all living systems. *Auto* means "self" and refers to the autonomy of a system that organizes itself; *poiesis* means "making." Autopoiesis is a network of production and processes, in which the function of each component is to participate in the production or transformation of other components in the network. In this way the entire network continually "makes itself." It is produced by its components and in turn produces those components. " In a living self-organizing system, the product of its operation is its own organization" (Maturana & Varela, 1980, p.82).

An important characteristic of an autopoietic organization is the creation of a boundary that specifies the domain of the network's operations and defines the system as a unit. (Capra, 1996; Jantch, 1980; Lichtenstein, 1998). To that extent, an autopoietic system is both open and closed: the boundary is permeable enough to be open to information and energy from the environment (Prigogine, 1996), while allowing the internal autonomy of the system to organize itself around its own survival (Maturana and Varela, 1987).

Autopoiesis describes the *pattern* of organization within a living system, characterized as the configuration of relationships that determine the system's essential characteristics (Capra, 1996; Maturana and Varela, 1987). Dissipative structures describe the *structure* of a living system, characterized as the physical embodiment of the system's pattern of organization (Prigogine, 1996). The activity involved in the continual embodiment of the system's structure and pattern of organization, as characterized by Maturana and Varela, is the *process* of a living system.

Maturana and Varela (1987) view change as a constant process within a system that continually pushes itself to higher forms of organization through structural connections with the environment. They describe the linking process with the containing environment as *structural coupling*, leading to structural congruence. Information from the environment acts as positive feedback on the system, which leads to behavioral iterations according to the system's own structure and meaning. Such iterations can produce energy or growth spurts, and thus contribute to disorganization (mathematical chaos) and rapid change. System limitations (i.e. resource limitations or formal rules) constitute negative feedback that simultaneously iterates through the system, thus damping down tendencies to cycle out of control. As a living organism responds to environmental influences with its own structural changes, these changes will, in turn, alter its future behavior. As such, a structurally coupled system is a learning system; its continual structural changes are a result of continuing adaptation, learning and development (Maturana and Varela, 1987; Warren, et al, 1998).

According to Maturana and Varela (1987), cognition, the process of knowing, is identified with life itself. In their view, cognition is not a representation of an independent, pregiven world, but rather a bringing forth of a world, one that is always dependent upon the organism's structure. For human beings, cognition involves language, abstract thinking and symbolic concepts based on beliefs, values and emotions. The linguistic domain of humans also includes the processes of self-reflection and consciousness, the level of cognition that is characterized as self-awareness. The uniqueness of being human lies in our ability to continually weave the linguistic network in which we are embedded. In language, we coordinate our behavior, and together in language we create our world, a "world which we bring forth with others through abstract thought, concepts, symbols, mental representations, and self-awareness" (Maturana and Varela, 1987, p. 245).

Luhmann, a sociologist, describes the autopoietic network in a human system as a process of communication: "social systems use communication as their particular mode of autopoietic reproduction" (Luhmann, 1990, p. 104). He uses a family system to exemplify a network of conversations that exhibit inherent circularities. The results of conversations give rise to further conversations, thus forming self-amplifying feedback loops. The autonomous nature of the autopoietic network results in a shared system of beliefs, explanations, and values—a context of meaning—that is continually sustained by further conversation (Capra, 1996).

Complex Adaptive Systems

A *complex adaptive system* is a self-organizing, self-reflective community of intelligent agents capable of learning and adaptation (Morel & Ramanujam, 1999; Pascale, 1999). It is made up of interacting *agents*, or system components, whose behavior is driven by adaptive rules. These rules lead them to examine each other's behavior in order to choose their own behavior in relation to others within the system they comprise. One set of rules is for performing tasks, evaluating their performance and changing the rules as needed to survive; another is for replicating themselves from one generation to the next. Some of the rules are conscious and explicit; others are implicit and unconscious (Goldstein, 1994; Stacey, 1996).

Because complex adaptive systems are self-organizing learning systems that function in environments containing other complex adaptive learning systems, "it follows that together they form a co-evolving suprasystem that creates and learns its way into the future" (Stacey, 1996). Agents within a complex adaptive system operate within a collective schema as well as unique individual schemata for interpreting their context and 1) adapting behavior according to its consequences (simple or single-loop learning), or 2) changing schemata that occur in the form of creative shifts during conditions far from equilibrium (complex or double-loop learning).

Processes inherent in complex adaptive systems can evoke order out of chaos, accepting that chaos is essential to the process. Through spontaneous self-organization, creative transformational shifts occur. Networks of agents within complex systems, driven by their own iterative, nonlinear, positive feedback cycles, produce unknowable outcomes that have pattern and coherence. Environments of systems within systems continually change, requiring rules within an organization's shared schema to be continually adapted to fit existing conditions. In complex human systems, individuals choose behaviors according to their own unique schemata, in addition to shared organizational schemata, thus adding additional iterations of complexity and creative potential.

A summary of key characteristics common to complex adaptive systems, which reflect complexity theories outlined in the preceding pages, is listed below.

- Component parts of complex adaptive systems do not interact in a linear, straight-line, direct cause-and-effect sequence but rather display nonlinear, oscillating, random-like dynamics.

- Because movements are nonlinear, exact prediction and control are not possible.

- Nonlinear interconnectedness within self-organizing systems results in self-reinforcing feedback loops that lead to increased complexity.

- Patterns of behavior in nonlinear dynamical systems tend to be self-similar in nature.

- System behaviors are highly sensitive to initial conditions and can be expected to exhibit unpredictable variability and diversity of movement over time.

- Simple rules may produce an unsuspected richness and variety of complex behavior while complex and seemingly chaotic behavior can give rise to ordered structures and sophisticated patterns.

- Boundaries are permeable, allowing energy and information from the environment to continually flow through the system while allowing the autonomy necessary for mutual interdependence and self-organization.

- Self-organization operates far from equilibrium; emergence of new structures and forms of behaviors occurs only when they system is far from equilibrium.

- Systems are able to create novel structures and models of behavior in the processes of development, learning, and evolution needed to sustain themselves.

The Study of Organizational Change and Transformation

Social scientists have tended to view organizational change and transformation as continuous and nonchaotic, in part because of the idealized goal of prediction and control, as well as the natural tendency to use research methods already known (Gregersen & Sailer, 1993). Phenomena are inclined to be modeled, as if they were linear, and behavior aggregated, as if it is produced by individuals who all exhibit average behaviors (Anderson, Meyer, Eisenhardt, Carley & Pettigrew, 1999). However, an increasing number of social scientists are beginning to explore the study of organizational change and transformation through the lens of complexity models.

The study of organizational change and transformation has experienced its own evolutionary metamorphosis since introduction of Lewin's classic model of change in the 1950s. The Lewinian model can be described as a linear movement through stages of change: from the equilibrium state "unfreezing", through the state of disequilibrium in which change is "introduced," back into a state of equilibrium referred to as "refreezing" (Hatch, 1997). Expanded perspectives of change have emerged from this model. For example, Kanter, Stein & Jick (1992) describe the simultaneous occurrence of change at three levels of analysis: environment, organization, and individual. Gagliardi (1986) introduced a symbolic interpretive model of change based upon the relationship between culture and strategy. He traced three types of change: *apparent change*, in which only superficial change occurs, *revolutionary change* that is imposed within a context of incompatible cultural assumptions, and *cultural incrementalism* which impacts deep-level cultural values and assumptions. Hatch's (1997) cultural dynamics model reinforces the link between cultural values and assumptions, and symbolization and interpretation, as an approach in which members of an organization create change.

Additional perspectives of change include the theory of *punctuated equilibrium* in which long periods of stability (equilibrium) are punctuated by compact periods of change (disequilibrium) (Gersick, 1991; Tushman, Newman and Romanelli, 1986; Sastry, 1997). Greenwood and Hinings (1993) identify the archetype as an important concept for understanding change. Large-scale, frame-breaking change (punctuated equilibrium) involves the movement form one archetype to another. Archetypes are best understood through analysis of patterns seen as functions of ideas, beliefs and values (components of an interpretive schema) viewed from a holistic perspective. Skoldberg (1994) examines change from the perspective of deep structure revealed through the narrative. Van de ven and Poole (1995) provide a perspective for the development of change in organizations by outlining four types of change theory from which, in their view, all specific theories of organizational change can be derived.

While none of these studies are explicitly linked with theories of complexity science, a cursory review suggests that elements within at least some of the theoretical frameworks could be described in the language of complexity. For example, descriptions of punctuated equilibrium suggest the escalation of positive feedback leading to a bifurcation point, in which a structural transformation(s) emerges. The notion of archetypal patterns (Greenwood & Hinings, 1993) imply self-organizing order; the study of simultaneous change in individuals, organizations, and environments (Kanter, Stein & Jick, 1992) could be viewed from the perspective of interrelated nonlinear subsystems within systems that may exhibit self-similar (fractal) characteristics. In Hatch's (1997) work, symbolic interpretation related to cultural change is described as a nonlinear and dynamical process. Overall, however, there seems to be an underlying assumption that although a state of disequilibrium may be necessary for transformative change to occur, the desired state of being—the place in which the system returns after *the* change(s) occurs—is one of stable equilibrium. In addition to the implied tendency toward system balance and stability, many of the studies seem to reflect an objective voice of logical positivism that assumes a responsibility to analyze, measure, predict or control perspectives and outcomes related to strategies for change.

A number of studies in the social science literature make an explicit link between elements of complexity science and human phenomena in organizations. For example, Brown and Eisenhardt (1997) expand the view of punctuated equilibrium by creating a multiple-product innovation model, which links complexity and time-paced evolution in "relentlessly shifting" organizations. Lichtenstein (1998) used the concept of *autogenesis* (described as an adaptation of autoeiposis) to develop a model of change for entrepreneurial organizations that allows for the integration of *deep structure* (i.e., self-organized core identity and regenerative rules) and *surface structure* (i.e. self-organized strategy control systems influencing the pace of change). Numerous organizational theorists have produced proposed frameworks for organizational analysis and change based on nonlinear dynamical systems models and related theories chaos and complexity (Anderson, et al 1999; Bartunek, 1994; Cheng & Van de Ven, 1996; Dooley & Van de Ven, 1999; Stacey, 1996; Theitert & Forgues, 1995). In addition, a few studies were found that empirically examine the dynamical changes within organizational settings (Greshov, Haverman & Olivia, 1993; Kiel & Elliot, 1996; Cheng & Van de Ven, 1996).

The June, 1999 issue of *Organizational Science* was devoted exclusively to articles in which organizational theorists explored the use of complexity theories in organizational systems in hopes of "sharpening our appraisal of the promise and limitations of complex systems theories in the study of organizations" (Cohen, 1999). Dooley and Van de Ven (1999) established a framework for deciding which kind(s) of process theory is best suited for explaining the dynamics of a particular empirical time series. They provide a clear procedure for determining the type of causal model that would be most appropriate to illustrate how sequence data in an innovation study might appear in different forms. Morel and Ramanujam (1999) use graph theory to explain what it means to say that complex adaptive systems self-organize, as distinguished from deterministic models of self-organization. Frank and Fahrback (1999) adapt social network models by turning them into dynamical systems, while Sterman and Wittenberg (1999) simulate an ecology of interacting, competing schemata by including positive feedback loops in their model that serve to generate sensitivity to initial conditions.

Kauffman (1993), a theoretical biologist at the Santa Fe Institute who introduced elements of complexity into Darwinian theories of evolution, formulated the *NK model* based on Boolean networks, a frequently used method for mapping complex systems. This model consists of two system parameters that can be manipulated for study: *n*, the number of elements in the network, and *k*, the number connecting relationships. Several organizational theorists have explored the use of this model in human systems. McKelvey (1999) sees the model as a critical tool for use in social science research; however, he expresses concern about elements of the model which may not accurately represent the "heterogeneity among agents and their inputs [found in human systems], instead of trying to average them away" (McKelvey, 1999, p. 234). Boisot and Child (1999) developed an "I-Space" model based upon Kauffman's *NK model* in which they posit that organizations are interpretive systems that first create, then objectify, the world through structuration. Their model suggests a poised state between a chaotic regime and an ordered regime where complexity is balanced between reduction and absorption. Levinthal and Warglien (1999) employ the *NK model* to bring a new perspective to organizational design based on the perceived need for either independence or interdependence of agents relative to an actionable objective.

Scientists in the field of psychology and sociology also are exploring human phenomena from the perspective of complexity science. According to psychological constructivists, a person's development of a sense of self goes through a process similar to Maturana and Varela's structural coupling. A person adapts new knowledge from his or her environment to match his or her personal meanings. Any pushes for personal changes in self from the environment are subsumed under the person' core constructs or present experiential order. Life experiences, and subsequent pushes from the environment, however, result in the "discontinuous emergence of more inclusive knowledge of self and of the world" (Guidano, 1991, p. 9). This also means that as a person adapts to the environment, he or she also changes the environment, which in turn is influencing the person. Thus, a recursive feedback loop is established and maintained (Warren, et al, 1998).

When people make substantive changes in psychological or social realities, they experience upheaval and change quickly. These periods of upheaval may be followed by periods of subjective stability, which is only transitory since some form of adaptation and change between the environment and the person is continually occurring. When individuals make transformational changes, they always take something of what they were before with them, but essentially become "newly organized" persons. They may, for example, take on a new identify or self-reference with groups or ideas (Warren, et al, 1998).

Sociologists have determined that human social systems are marked by rapid shifts in the level of self-organization (Harvey & Reed, 1994). It may be possible to anticipate—and invite—the initial conditions needed for such transformational shifts in perspective within group and organizational settings. These transformations may not require an enormous amount of input. The nonlinear feedback loops inherent in complex systems means that small changes can result in dramatic effects. Family therapists have borrowed from the ideas of Maturana and Varela, Prigogine (1996), and others to introduce strategic interventions into a family system in ways that produce rapid change (Warren, et al, 1998). Keeny, for example, views family systems to be in a constant state of change in which an intervention can serve as a meaningful perturbation that reverberates throughout the system in an unpredictable way, producing self-organized change. Warren, et al (1998) note that while these ideas are valued in the field of family therapy, they have not yet been developed extensively in other social science contexts.

The study of connectionism within neuro and sociodynamical phenomena has been enhanced by empirical studies developed from complexity models. For example, the brain's continuous interaction with the environment results in chaotic activities whose main functions are to provide access to previously learned patterns or to learn new patterns. Patterns of cognitive s*paces* (bifurcation points) hidden in complex dialectic systems serve a critical cognitive function by giving the brain a suspended moment of time before constructing new meaning or reorganizing its existing meaning structure (Warren, et al, 1998).

Developmental psychologists, through empirical work, posit that as subsystems develop and interact, they periodically reach a point analogous to the phase transition of mathematical chaos. Because of sensitive dependence on initial conditions, these states offer possibilities of rapid and transformational change, and also show greater variability than other periods of growth. Through a measurement system used to determine where change occurs, they found that people usually enter into a form of internal disequilibrium before they make decisions (conscious and unconscious) to change. When change does occur, however, it is often rapid and discontinuous (Thelen & Smith, 1994).

Brief therapy models, grounded in a cognitive or social reconstruction, reveal unanticipated perturbations from the environment leading to upheavals in a system, which, in turn, trigger a self-organizing process that may transform social constructions and beliefs, and thus produce second-order changes in a system's structure and functioning capability. These theories are drawn on the work of Bateson (1972) and others, who subscribe to second-order cybernetics and nonlinear epistemology. Techniques for responding to the natural change process, highlighted in the social construction model of brief therapy, include circular questioning, use of paradox and counterparadoxical interventions (Fraser, 1995; Watzlawick, Weakland & Fisch, 1974).

Stacey (1996) combines perspectives from the sciences of complexity, psychology (Klein, 1975; Winnicott, 1971) and group process (Bion, 1961) to create a socially constructed model for creativity in organizations. He argues that the creative process in an individual's mind, a group, or an organization, takes place at the edge of chaos, and involves the paradoxical and simultaneous processes of disintegration and collaborative creation. Cross-fertilization of diverse perspectives acts as positive feedback balanced by the damping down effect of negative feedback in the form of formal organizational structures and rules. In Stacey's (1996) view, authentic dialogue—a creative human process that is often uncomfortable and messy involving difference, conflict, projection and emotion—is an example of cross-fertilization that constitutes positive feedback in human system, thus creating self-perpetuating energy for transformational change.

Many articles and books have been written about chaos and complexity science that are written primarily for practitioners of social change in businesses and institutions. Though less scientifically descriptive than scholarly works, these publications offer comprehendible accounts of relevant complexity concepts, particular in managerial contexts, as well as rich examples of change experiences that “make sense” through the lens of complexity science. (Golstein, 1996; Heifetz & Laurie, 1997; Pascale, 1999; Stacey, 1992; Wheatley & Kellner-Rogers, 1996).

While there is no single and unified theory of complexity (Cohen, 1999), there are provocative emerging models and methodologies in the physical and biological sciences that are providing new perspectives from which to view transformational change in the context of complex adaptive human systems.

The Social Construction of Organizational Transformation in a Complex Adaptive System

The view of social constructionism suggests that complex adaptive human systems are created through social interaction, i.e., discourse. Meaningful discourse is the result of social interdependence and requires the coordinated actions among members of the organizational system (Gergen, 1994; Pearce & Littlejohn, 1997). At the most basic level, discourse is “what is said and listened to” between and among people (Berger & Luckmann, 1966). Described more fully, discourse is a complex information-rich mix of stimuli that includes not only what is spoken, but also the full, conversational elements of behaviors, symbols and artifacts, etc. that are used in conjunction with, or as substitutes for, what is spoken. Conversations maintain realities through an accumulated mass of continuity, consistency, and relatedness to other conversations (Berger & Luckmann, 1996; Watzlawick, et al, 1974).

Constructionism does not necessitate the abandonment of traditional pursuits of knowledge. “Rather, it places them within a different frame, with a resulting shift in emphasis and priorities” (Gergen, 1994, p. 30). Social construction invites new forms of inquiry, substantially expanding the potential for generative, collective knowledge. It is a form of intelligibility—an array of propositions, arguments, metaphors, narratives, etc.—that welcomes inhabitation. In the context of social constructionism, “individuals are invited to ‘enter in’ the generation of a meaningful reality: to collaborate in giving the array a sense and a significance, to play with the possibilities, and the practices coherent with the existing intelligibility, and to evaluate them against alternatives” (p. 79).

Building on the work of George Herbert Mead, Gergen describes *intersubjective interdependency* (1994, p. 216) as a way of viewing relationships that seek to coordinate mentalities. Human beings almost instinctively coordinate their actions. As their coordinated development proceeds, they acquire the capacity for self-reflection—consciousness of themselves and the effects of their actions. Self-consciousness, in turn, is influenced by adopting the standpoint of the other toward the self. Thus, one’s conception of self and one’s actions are essentially dependent on the attitudes and actions of others; “there is no self and no meaningful action without dependency” (Gergen, 1994, p. 216).

Therapists, counselors, and organizational consultants have enormous potential for enhancing cultural transformation from a social constructionist perspective by developing new forms of interaction with their clients (Gergen, 1994), thus modeling ways in which the culture may be informed of alternative ways of creating knowledge. For example, “when consultants *create* (emphasis added) dialogue across the strata of an organization (as opposed to offering authoritative solutions), they implicitly create the reality of interdependence” (p. 62). In co-constructing reality with the client system, the practitioner is a potential agent for far-reaching change outside of the existing paradigm of the system.

Few studies explicitly relate elements of complexity theories with perspectives of social constructionism and transformational change. However, examples of studies by developmental psychologists and psychological and social constructivists (Harvey & Reed, 1994; Warren, et al, 1998), along with characteristics of social constructionism described by Gergen and others, suggests opportunities for further exploration.

Research Propositions

The following propositions are examples of provisional links between perspectives offered by complexity theories and the social construction of transformational change. These propositions suggest a starting place from which to launch additional research needed to develop a framework for transformational change in organizations.

- The creative capacity of human beings within a complex adaptive system is *highly sensitive to, and dependent on, initial conditions* for functional interaction, thus impacting the system's tendency to perform at the *edge of chaos*. The implication for organizational members and OD professionals is that they must be concerned with how to create the initial conditions, grounded in authentic interaction, diverse human experience, and collaborative inquiry, which is necessary to unleash creative potential for resolving issues that impact the organization's sustainable future.

- The experience of "staying in" ambiguity, tension and paradox in the context of authentic dialogue long enough to understand multiple perspectives creates the potential "heat" (*far-from equilibrium conditions within a dissipative structure*) needed for members to experience a transformational shift to a new conceptual frame of reference. The heightened level of information and energy created by tension increases connectivity among system components which, in turn, enables them to self-organize around an evolving understanding of their collective purpose. Tension and ambiguity hold the seeds for collective creativity, renewal, and replenishment for the whole system. The implication for organizational members and OD professionals is the need to create dialogue-rich environments that foster courageous and authentic conversations about how to achieve and sustain optimal performance capability.

- The role of leadership within a complex adaptive system shifts from one characterized by command and control actions that reflect assumed responsibility for providing organizational vision and direction, to one that relinquishes command and control assumptions and, instead, embraces the *autopoietic capability of the system*. "In a living self-organizing system, the product of its operation is its own organization" (Maturana and Varela, 1987). When authoritative leadership is minimized, the *collective leadership* becomes fully engaged in the generative discourse needed to identify challenges and create strategies for a sustainable future in a continually changing environment. The model of the leader-who-has-the-answers is replaced by a model of integrated leadership that emerges from the collective wisdom within the system. The implications for formal organizational leaders and OD professionals (who perform in a temporary leadership role as system advisors) suggest a dramatic shift *away* from the predominance of the traditional authoritative or objectively assertive role of direction and "expert" advice, toward the subjectively integrative role (Capra, 1996) of co-collaboration and co-creation of a shared social reality.

The complex realities of today's world suggest that the continuing study of transformational change in human systems is a worthwhile endeavor. Theories emerging within the sciences of complexity offer new models from which to understand transformational change within social systems in radically new ways. A framework that serves to guide the social construction of transformational change needed to work toward a more sustainable future may be a worthy goal for future research.

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