Winter 12-19-2001

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Abstract

Traditionally, management has viewed the organization as a very mechanistic, linear system characterized by a simple and predictable cause and effect. However, complexity theory brings to management an organic, nonlinear, and holistic way of viewing organizational systems. Within the business context in general and the electronic commerce model in specific, the self-producing and self-organizing nature of the organization combined with the interaction between the autonomous agents of the system, produces emerging patterns and an intrinsic order that flies in the face of the traditional problem-solving techniques. The application of the autopoietic and complexity theories to the virtual systems that exist within the electronic commerce model can assist business management in understanding the nature of the unpredictable, dynamic forces continuously driving forward the dynamics of these New Economy systems. The focus of this research will center on:

- identifying the interactive nature of complexity theory within the electronic commerce model;
- understanding the virtual society of the electronic commerce model as being functionally differentiated into autonomous autopoietic subsystems, or "meaning worlds" (Teubner & Willke, 1997), which can influence each other only indirectly;
- accepting that functional differentiation, complexity theory, and autopoiesis mean it is no longer possible to direct and control these virtual social systems to move along the traditionally predetermined paths through interventions from external systems, such as external entities, business alliances, internal customers, or external customers;
- appreciating the creative dynamism unleashed through complexity theory and the autopoietic processes in which the new hyper-extended communication acts to produce new artificial structures within the electronic commerce model that have dynamics of their own and can self-reproduce and self-regulate through autopoiesis;
- being aware that these social autopoietics do not give primacy either to the individual or the collective within the virtual social system, but to the emergent new hyper-extended communication system which results from discourses involving the dynamic systemic structures and real people.

Hypothesized outcomes of this research also include a better understanding of the emergent behavior of the systems within the electronic commerce model. The application of the autopoietic and complexity theories to these virtual systems can be positively related to organizational success that comes from the networked combinations of freely acting agents. Competitive advantages can be maximized and organizational missions can be achieved though an understanding and application of complexity and autopoietic theories.

Backgrounding the Issue

The complex organizational system has been a central topic in organizational studies for decades (Heylighen, 1997). However, the literature has neither fully explored the multiple interacting components of these systems nor the resulting organizational behavior that simply cannot be inferred from that of its components. "General systems theory approaches to administration routinely consist of linear dynamics explained in the equation:

INPUT → PROCESS/CHANGE → OUTPUT

Such approaches are naive in nature and do not delve into the complex interaction of various sub-components of systems. In addition, the synergistic effect of sub-component interaction is often explained away or ignored outright!" (Carter, 1997).

Moreover, there is little research into the problems facing managers and how they might better be solved using non-linear methodologies. Too often these systems, which are nonlinear, deterministic, and behave in apparently unpredictable and chaotic manners, have been studied using linear methodologies.

There is a trend toward the use of predictive systems in communications networks. At the systems and network management level predictive capabilities are focused on anticipating network faults and performance degradation thus improving predictive maintenance. Simultaneously, mobile communication networks are being developed with predictive location and tracking mechanisms. The interactions and synergies between these systems present a new set of problems not easily predicted using linear methodologies (Bush, Frost and Evans).

There is a growing sustainability crisis in organizations. Adapting to a globalized, hyper-competitive economy is fraught with technological change, disintegrations, and new alliances (Merry, 1995). The merging of disciplines in the field of complex systems may run counter to the increasing specialization in information systems, business management, and network management, but it provides many opportunities for synergies and the recognition of general principles that can form a basis for new understanding. Complexity theory, chaos theory, dynamic nonlinear systems theory, and self-organization theories of the New Science are altering the methodologies and basic questions of management and organizational inquiry. They are also creating a new metaphorical vocabulary that can help managers see organizational behavior in a new light. These lessons hold important implications for innovation and emerging technology management and provide scholars and practitioners alike useful templates to follow when analyzing complex processes that involve organizations (Voehl, 1999).

Introduction

The modern notion of chaos describes irregular and highly complex structures in time and space that often hide simple deterministic rules (Mayer-Kress, 1995). This is in contrast to the structureless chaos of traditional equilibrium thermodynamics. This theory contends that once these rules are found it will be possible to make effective predictions and even to effectuate control of the apparent complexity (Lissack, 1996). The appeal of 'making the complex simple' and of extending spheres of control has led to many misunderstandings of what complexity theory is and what relevance it may have to the world in which we live (Lissack, 1996). Most management complexity authors begin with justifying the significance of complexity theory by listing the deficiencies of pre-existing management theories including its "unacknowledged but self-imposed limitations…" (Rosenhead, 1998).

Systems are integrative and highly interactive. We usually think of a system as closed and as having a definite boundary(ies), yet the boundary may be permeable.

"When one views a system dynamic from a linear frame of reference, one assumes that a closed system (one with a solid, relatively impermeable boundary) exists. Closed systems have a tendency towards entropy and collapse" (Carter, 1997).

Open systems have permeable boundaries that allow for the influence of outside source on the system sub-components and the system as a whole. Yet, contemporary literature attempts to explain the multi-dimensional constructs of open systems in a linear fashion. (Carter, 1997).

Business people tend to think about their world in a mechanistic, linear way where cause and effect are the underlying principle and behavior is predictable. Simple observation, however, shows the world to be predictably unpredictable. This is a key tenet of complexity theory; that the future is unknowable. Given that most managers feel part of their job is to decide where the organization is going and make decisions to arrive there, management complexity authors see this assumption as unrealistic at best and probably dangerous because the future in a complex system is unknowable.

Complexity theory looks at systems as nonlinear, anti-mechanistic, dynamic, and organic. "This idea that simple nonlinear deterministic systems can behave in an apparently unpredictable and chaotic manner was first noticed by the French mathematician Henri Poincare" (Herman, 1996). Most early work in the field of nonlinear dynamics was from a mathematical standpoint and the importance of chaos was not fully appreciated until the use of computers became widespread allowing the simulation and demonstration of chaos in physical systems. Other scientific disciplines began their own study of chaos and the field has seen explosive growth in the last decade. Biology, chemistry, economics, engineering, physics, and many more, have found the ideas of nonlinearity useful.

Modern science is founded on a linear, mechanistic paradigm that is breaking down. Our clockwork view of the universe spawned with the machine age is quickly giving way to findings of quantum theory, Heisenberg's uncertainty principle, and Godel's postulations. As the information age is achieving prominence so the industrial age and its backbone of Newtonian physics is breaking. Some of the questions we are finding with the old science include the idea that the world is not linear; that things cannot be understood by looking at their parts; that we can study phenomena by separating the observer from the observed; value-free statements can be made by science; boundaries are clearly defined; an experiment can be tested for validity through replication of the experiment (Merry, 1998). To simplify, we are finding that things are much more complex than we once thought and the complexity of systems leads to unpredictability.

Modern science cannot be used to describe our reality or solve the nonlinear problems in complex systems. Merry notes that these are precisely the problems the Information Age is highlighting (2). "These are problems of change in organizations and other human systems, of different states in these systems, of how complex systems adapt to their changing environments, of evolution and selection that is not only in the hands of chance. If scientists are having difficulty with the new paradigms, imagine the difficulty of those in corporations and society at large who have no tools - conceptual or methodological - and no experience in dealing with these issues." (Merry, 1998). It is the advent of computers and their ability to deal with nonlinear equations and their ability to simulate complex systems that have allowed the New Sciences to advance. "Computers gave the New Sciences the ability to simulate and thus address and study phenomena such as nonlinearity, interconnectedness, complexity, emergence, chaos, self-organization, punctuated change, adaptation, evolution, sustainability, learning, fitness, reproduction, selection and many other important states and processes." (Merry, 1998).

The idea of complexity in organizational studies is not new. The theories have generated much literature, along with a specialized language, written by scientists in their own research field. There is also a growing literature written by authors experienced in management and organizational behavior drawing on this work to address management concerns and practices (Rosenhead, 1998). The last few years have seen an extraordinary growth of interest in the study of complex systems. From ecology to economics, from particle physics to parallel computing, a new vocabulary is emerging to describe discoveries about wide-ranging and fundamental phenomena. Many of the terms have already become familiar: artificial life, biocomplexity, cellular automata, chaos, criticality, fractals, learning systems, neural networks, non-linear dynamics, parallel computation, percolation, self-organization, and many more. As the general public has become more familiar with the vocabulary of complexity, the ascribed claims for complexity theory have also increased (Lissack, 1996).

Vocabulary and Definitions

Because the scientific and management communities seem to embody the very words used in complexity research with a variety of meanings, it is essential to begin with a set of definitions. Mike McMasters has suggested the following as "operational definitions for management and organizational purposes:

chaotic refers to a state where patterns cannot be made nor details understood,

complicated refers to a state where patterns cannot be made but details, parts and subsystems can be understood, and

complex refers to a state where the details cannot be understood but the whole (or general result) can be understood by the ability to make patterns." (McMasters, 1995).

Complexity theory is the generalized name for the field. Chaos is a particular mode of behavior within the field (Rosenhead, 1998). Chaos and complexity theory is about recognizing patterns in the seemingly unexplainable and using these patterns to gain greater understanding. Values measurement is about understanding and recognizing patterns of human and organizational behavior. In other words, values (and values measurement) can help one to understand some of the seemingly chaotic behavior that goes on in organizations (Hall, 1998).

System

A system is a group of interacting parts functioning as a whole and distinguishable from its surroundings by recognizable boundaries. There are many varieties of systems, on the one hand the interactions between the parts may be fixed (e.g. an engine), at the other extreme the interactions may be unconstrained (e.g. a gas). The systems of most interest in the context of management and complexity theory are those in the middle, with a combination both of changing interactions and of fixed ones (e.g. a cell). The system function depends upon the nature and arrangement of the parts and usually changes if parts are added, removed or rearranged. The system has properties that are emergent, if they are not intrinsically found within any of the parts, and exist only at a higher level of description (SOS FAQ, 1999).

System property

When a series of parts are connected into various configurations, the resultant system no longer solely exhibits the collective properties of the parts themselves. Instead any additional behavior attributed to the system is an example of an emergent system property. A configuration can be physical, logical or statistical; all can show unexpected features that cannot be reduced to an additive property of the individual parts. (SOS FAQ, 1999).

Emergence

The appearance of a property or feature not previously observed as a functional characteristic of the system. Generally, higher-level properties are regarded as emergent. An automobile is an emergent property of its interconnected parts. That property disappears if the parts are disassembled and just placed in a heap. This is a basic tenet of complexity theory. It is because of emergence the prediction of organizational behavior is unpredictable. (SOS FAQ, 1999).

Fitness Landscape

Wright first used the term fitness landscape in the 1930's in the field of evolutionary biology. A fitness landscape is a "mountainous terrain showing the locations of the global maximum (highest peak) and global minimum (lowest valley) [and] the height of a feature is a measure of its fitness." (Coveney and Highland, 108) Competition can be said to occur on a fitness terrain. That terrain itself is not fixed but changes and deforms as the actors within its sphere act and change and as the general environment changes. Kauffman states, "Real fitness landscapes in evolution and economies are not fixed, but continually deforming. Such deformations occur because the outside world alters, because existing players and technologies change and impact one another, and because new players, species, technologies, or organizational innovations, enter the playing field." (Kauffman and Macready) "Fitness landscapes change because the environment changes. And the fitness landscape of one species changes because the other species that form its niche themselves adapt on their own fitness landscapes . . . "(208) We can construct such a landscape for any system of connected interactions (such as a firm and its environment), and it is the presence of "conflicting constraints that makes the landscape rugged and multi peaked. Because so many constraints are in conflict, there are a large number of rather modest compromise solutions rather than an obvious superb solution." (173).

Organization

The arrangement of selected parts so as to promote a specific function. This restricts the behavior of the system in such a way as to confine it to a smaller volume of its state space. (SOS FAQ, 1999).

State/Phase Space

This is the total number of behavioral combinations available to the system. When tossing a single coin, this would be just two states (either heads or tails). The number of possible states grows rapidly with complexity. If we take 100 coins, then the combinations can be arranged in over 1,000,000,000,000,000,000,000,000,000,000 different ways. We would view each coin as a separate parameter or dimension of the system, so one arrangement would be equivalent to specifying 100 binary digits (each one indicating a 1 for heads or 0 for tails for a specific coin). Generalizing, any system has one dimension of state space for each variable that can change. Mutation will change one or more variables and move the system a small distance in state space. (SOS FAQ, 1999).

Self-organization

The evolution of a system into an organized form in the absence of external constraints.

A move from a large region of state space to a persistent smaller one, under the control of the system itself. This smaller region of state space is called an attractor.

The introduction of correlations (pattern) over time or space for previously independent variables operating under local rules (SOS FAQ, 1999).

Attractor

An attractor is a model representation of the behavioral results of a system. The attractor is not a force of attraction or a goal-oriented presence in the system, but simply depicts where the system is headed based on the rules of motion in the system (Lissack, 1996). The term is descriptive, but the word itself seems to imply a prescriptive force. For the practicing manager, one more word must be added – “passive.” The attractor just is, it is a passive being not an active force. But, being passive means that the actors can drift from one attractor to another (Lissack, 1996).

An attractor is the preferred position for the system, such that if the system is started from another state it will evolve until it arrives at the attractor, and will then stay there in the absence of other factors. An attractor can be a point (e.g. the center of a bowl containing a ball), a regular path (e.g. a planetary orbit), a complex series of states (e.g. the metabolism of a cell) or an infinite sequence (called a strange attractor). All specify a restricted volume of state space (a compression). The larger area of state space that leads to an attractor is called its basin of attraction and comprises all the pre-images of the attractor state. The ratio of the volume of the basin to the volume of the attractor can be used as a measure of the degree of self-organization present. This Self-Organization Factor (SOF) will vary from the total size of state space (for totally ordered systems - maximum compression) to 1 (for ergodic - zero compression) (SOS FAQ, 1999).

Complexity Theory and Management

"In attempting to increase flexibility in dealing with the crunch economy and hyper-competition, organizations resort to downsizing their workforce, enlarging the number of temporary workers, and outsourcing parts of their production or other processes to places with lower labor costs. While these measures may be a stopgap for tightening budgets, some of them may misfire, and in the long run, they alone are insufficient to deal with the new conditions developing in the Information Age. The long run balance sheet of these measures is yet unclear." (Rosenhead, 1996.)

Two other trends are developing in reaction to the new conditions. The first is the creation of networks between organizations., partnerships, strategic development of a common This may take many forms such as alliances market, exchange of knowledge resources, joint marketing, etc. There are many successful examples of small businesses, such as the garment industries in Northern Italy, creating a common network for production, development and marketing. A second trend is the development of new organizational structures. Organizational structures are changing, becoming more plastic and flexible, resulting in new forms such as the virtual organization and autonomous subunits (Rosenhead, 1998).

One of the greatest challenges to organizations may be to executives and senior management. "Both the Knowledge Era and the Network Society are reducing the capacity of control and increasing the requirement of distributed intelligence and accountability. The move needed is toward autonomy and self-organization and away from central direction and control. The adjustment in thinking and attitude is proving extremely difficult for many of the formal leaders." (Merry, 1995).

Traditional wisdom says an organization should have a CEO overseeing a management team with a vision or strategic intent supported by a shared culture. The organization should focus on its core competency, build on its strengths, adapt to its environment, and keep a close eye on the bottom line. Goal and strategy formation, environmental analysis, and strategic control are the hallmarks of a viable organization. And all are wrong from a complexity theory management perspective. The traditional organization is seen as a clockwork machine following linear Newtonian rules. But complexity theory has shown the world does not operate this way. The world displays creative disorder (Lissack, 1996).

Ralph Stacey notes two kinds of managers. Ordinary management is needed to fulfill day-to-day problem solving through a linear, analytic process. Extraordinary management is required for the organization to transform itself when in the midst of open-ended and rapid change. Stacey adds that rational decision-making does not work here because the givens must be disputed (Stacey, 1993). Extraordinary management requires the development and use of tacit knowledge within the organization. How to achieve this is the question.

Kauffman suggests: defining the size and number of business units; defining the nature of interactions among these units; developing a language for dispersing information among these units; defining a strategy for “search”, hunting for improvements in the fitness landscape; and using “noise”. His research led him to use a metaphor called “simulated annealing”. The idea is that a system sometimes “ignores” existing constraints and takes a step in the wrong direction thus temporarily increasing its energy. He called this a “patch”. A system is partitioned on a complex landscape into smaller, independent departments, or patches, each of which optimizes selfishly. Since each is independent and selfish, actions of one department can improve and, almost accidentally, move the whole to a better state. For organizations this means to divide it into patches that interact and are independently optimized. Couplings will arise between patches and finding a solution in one will affect the problem to be solved in other patches changing the problems and solutions in yet other patches. The organization begins to look more like a coevolving, self-organizing, and complex adaptive system (Kauffman, 1995)

Globalization includes means finding solutions for how to deal with growing complexity and uncertainty. The acceleration in the rate of change, hyper-competition, the crunch economy, the knowledge landscape, the changes in the workforce, all create problems for organizations, which are complex systems, in the process of changing themselves to better adapt to new environmental conditions. They are problems of how to ensure organizational sustainability in a complex, uncertain, interconnected world. They are multi-layered, nonlinear, interconnected, dynamic, complex problems that Modern Science has difficulty dealing with. These are the kind of problems the New Science is attempting to address.

Complexity theory helps to understand the uncertain environment and the irregular effects of nonlinearity and interdependence on organizational functioning. It focuses attention on the different states the organization may be functioning in. It explains why sometimes large efforts give no results and at other times a minor change leads to an organizational landslide. It helps clarify the limits of predictability of long term strategic planning, especially in the kind of environment created by the Information Age. It brings to attention the irregular fractal forms of nature with their characteristic of self-similarity that might be a model for an organization.

Self-organization gives a framework through which to understand organizational change. It helps conceive how all organizations have within them the natural tendency to renew themselves through self-organization. Unless blocked, this is the major way by which organizations adapt themselves to their changing environment. It clarifies the difficulties of trying to control a process of this kind and in cases of organizational transformation the inability to predict the outcomes. It brings attention to bifurcation points in the organization's history, when such changes are immanent. Such transformations generally occur when cleavages within the organization are brought to a critical point by perturbations from outside the organization. Self-organization helps understand that such a process cannot be planned and controlled from above in a demand/control mode. It clarifies the emergence of new organizational forms from a change in the relationship of its components. Self-organizational changes follow a power law, which means that small changes take place often and major changes are extremely infrequent. All of this is most relevant to organizational change (Merry, 1995).

Complex Adaptive Systems (CAS) is a basic roadmap to understanding organizational functioning. It helps managers understand how an organization's behavior emerges from the interaction of its active components. It describes how organizations are built in the form of levels with one level containing the other. It clarifies how the organization can maintain a balance of change and stability by lower levels changing at a slower pace than higher levels. From CAS, it is possible to see how organizations learn by adapting schema or models through which they interact with their environment and change when needed. The way an organization adapts to its changing environment and co-evolves with other entities in this environment is made clearer by dealing with organizational landscapes. This makes it possible to think in terms of different organizational strategies in different landscapes. CAS leads to thinking about external strategy in terms of networks of alliances. The concept of "the edge of chaos" helps sort out the mix of continuity and novelty, order and chaos, tradition and innovation that furthers organizational learning and fitness. CAS theory guides ones thinking about an organizational structure which has much more flexibility, based on autonomous subsystems and managed by steward like leadership that encourages autonomy, creativity, interaction, diversity and openness and networking to the outside world.

Taking all of the New Sciences together as one whole, it is possible to discern the emergence of the fuzzy outline of a new paradigm that might serve as a base for approaching organizational issues in a world of growing complexity and uncertainty. This new paradigm is in the making, hopefully avoiding many of the pitfalls of an organizational paradigm based on Newtonian foundations. It is an approach that appears to be able to deal with the nonlinear, far-from equilibrium, dynamic, interconnected evolutionary complexes organizations have to deal with. It is an approach that holds promise for organizations.

Human systems of all kinds and at all levels are dividing into those who can deal with the new environmental conditions and those who cannot. This bifurcation is following the cleft of those that have succeeded in adapting to the Information Age and those who have not. In economic and development terms the countries of the world have bifurcated into those who are able to join the world network economy and those who have difficulty in doing so.

The same bifurcation process is taking place among organizations. Survival is a matter of being able to function effectively in the new condition of the Information Age, or not being able to do so. The complexes described above as introduced by the Information Age have created a new environment for organizations. The increasing interdependency and uncertainty of a networked world aggravate conditions. Among organizations there is a process of bifurcation between those that are able to adapt to these new conditions and those who have great difficulties adapting (Merry, 1995).

Conclusion

In the new, networked economy many organizations, especially the young and small, fall to the side. The economic systems in which we live are complex and unstable. Research into complexity theory and chaos has created a new metaphorical vocabulary that can help managers see their organization in a new light.

"Are traditional social science methods incapable of dealing with the complex and indeterminate problems facing management today? It is not so much the wedding of scientific logic and method to management theory and practice that is problematic, as it is the outdated models of scientific inquiry that slow our progress. The new sciences of chaos and quantum theory [complexity] offer valuable metaphors and methods that can challenge the management research agenda into the next century [with]... the image of self-organization, dissipative structures, and dynamic complexity (Overman, 1996).

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