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Educational Change through the Lens of Complexity Science: Changing Thinking for Changed Learners

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Abstract

As education professionals work in times of exponential change, how they think is as important as what they do. Our thought processes frame our creations—and for hundreds of years that frame has been a linear, Newtonian paradigm. Due to advances in hard sciences, we now know that there are other ways of framing our thoughts and understanding our world, and that is through complexity science. Complexity science is a powerful metaphor to use in reviewing our common understandings of school systems and how to reform them to better serve students. This paper includes a primer of complexity science terms and then uses those terms as a lens on school systems for educational professionals pursuing change to meet the needs of the Net Generation of learners as we move into the Information Age.

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ABSTRACT

As education professionals work in times of exponential change, how they think is as important as what they do. Our thought processes frame our creations—and for hundreds of years that frame has been a linear, Newtonian paradigm. Due to advances in hard sciences, we now know that there are other ways of framing our thoughts and understanding our world, and that is through complexity science. Complexity science is a powerful metaphor to use in reviewing our common understandings of school systems and how to reform them to better serve students. This paper includes a primer of complexity science terms and then uses those terms as a lens on school systems for educational professionals pursuing change to meet the needs of the Net Generation of learners as we move into the Information Age.

School reform is a phrase that belies the complexity of re-forming an education system. Previous ways of thinking about schools and educational design have not led to the advances educational professionals hope for in our schools. Another way to conceptualize schools and how they might embrace change is through complexity science. This shift in understanding has already happened in the hard sciences, and has catalyzed a turn away from old Newtonian conceptualizations of how systems behave. Complexity science informs around notions of complex adaptive systems, initial conditions, attractor states, and bifurcation. These ideas can be used as metaphors for understanding education systems and changes within them, as well as the consistent themes that repeatedly play out in schools. A general overview of complexity science follows which describes the terms complex adaptive systems, initial conditions, attractor states, and bifurcation through the language of complexity science. These terms will be used as a metaphor through which education systems can be understood in a new way. And finally, the reader is challenged to think on one facet of the educational system through the lens of complexity.

WHY A NEW FRAME IS NEEDED

This new understanding is imperative considering that the static space of the graded schoolhouse does not reflect the changed learners walking its halls. "Today's students are no longer the people our educational system was designed to teach" (Prensky, 2001, p. 1). Students have not simply changed incrementally compared to previous generations; a discontinuity has occurred. Prensky described this discontinuity as a "singularity—an event which changes things so fundamentally that there is absolutely no going back" (p. 1), a bifurcation. The Net Generation presents a point of no return to old teaching and learning conceptions. This generation has grown up with technology, such as computers, Internet, cell phones, and more. These tools, in part, have facilitated the Net Generation's abilities to read images with greater visual-spatial skills, learn better through inductive discovery, deploy attention selectively, and respond quickly while expecting quick response in return (Oblinger & Oblinger, 2005). The Net Generation has been steeped in, as Ventura describes, a timeless, spaceless environment of the Internet, 24-hour banking, shopping and television, light and change, instantaneousness; this is their natural habitat (1993). These digital natives, who not only invent new online ways of doing things but also the tools to do them (Prensky, 2001; 2004), are steeped in complexity, preferring to parallel process, multi-task, choosing random access, and functioning best when networked. They crave an interactivity that is simply not present in traditional schooling.

Some educators continue to see education as a linear transferring of information to a subject (Kim & Axelrod, 2005; Prensky, 2001). They spend time lecturing, teaching students how to use tools from the past with matching methodology, and measuring success through multiple-choice questions (Prensky, 2007). "But to today's kids, none of that is education" (Prensky, p. 1). They want to be a part of a community, work in groups, do projects, be asked interesting questions and engage with peers in a challenge. Prensky went on to state that teaching in the old "tell-test" paradigm is getting harder. The experience of learning is now acknowledged to include a variety of factors, like the nature of the content, learner styles, skills of the educators, learning space, and media and technology. A growing number of conceptions of learning more closely resemble a more complex view of teaching and learning (Siemens, 2007). Better understanding complexity science, and the terms associated with it, may help educators wanting to shift perspectives on how the traditional school serves its learners.

COMPLEXITY PRIMER

With well over 30 definitions of complexity science, a simple explanation of the theory does not exist (Richardson & Cilliers, 2001). However, certain terms are repeated through various perspectives of complexity science, including complex adaptive systems, initial conditions, attractor states, and bifurcation (Axelrod & Cohen, 2000; Capra, 2002; Cilliers, 1998; Gleick, 1987; Goerner, 1994; Richardson & Cilliers, 2001), and these will be explored here as well.

Disturbing to a mind that desires regularity, order, and predictability, conceptualizations of complexity affect no less than our entire understanding of what it means to live in time (Peat, 2002, p. 116). This perturbation began in the early 1900s with the work of mathematician and philosopher Henri Poincare as he broke from a positivistic view of science and began to question the predictability with which our most obvious assumptions are made, for example the notion that the sun will rise and set every day (Peat, 2002). His work set the stage for the complexity science of today. Because we are a part of any system that we investigate, we are unable to see it as detached observers might. This invites uncertainty into every observation and leads us to realize that we may never be able to fully detail a complex system. Incomplete knowledge (Peat, 2002) is held by agents of any system and since no agent has access to an

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external reality, knowledge is subjective.

Systems containing these agents that are able to interact and change are known as complex adaptive systems and they provide one way of conceptualizing complexity science (Axelrod & Cohen, 2000). Here, systems of agents are the primary movers. And even with the most strategic planning, cause and effect are not always clearly foreseen. Central to this notion is the multi-agent system in which agents locally and autonomously interact but yield a pattern of global order. Agents are "intrinsically subjective and uncertain about the (global) consequences of their actions, yet they generally manage to self-organize into an emergent, adaptive system" (Heylighen, Cilliars, & Gershenson, 2006, p. 17). From this self-organization emerges novelty. In addition, while agents' actions may lead to unforeseen consequences in a space, these systems are also influenced by pre-existing states, or initial conditions.

The initial conditions of a system's development are pivotal in how its evolution proceeds. Edward Lorenz first documented this realization in the 1960s while studying weather (Gleick, 1987). He used a computer model to investigate weather patterns, looking for predictability in an attempt to better understand disturbances. In one instance, Lorenz began a simulation by inputting a later point in the data series, but using the same information – changing the initial conditions, the numbers representing the starting point (Capra, 2002). The results were entirely different than in the previous model, in which the simulation had run from the original initial conditions. From virtually the same starting points, two models developed in entirely different ways. From this Lorenz posited that small changes in the initial conditions of a system might achieve large consequences in how evolutionary patterns develop and thus displayed our limited ability to predict from data.

While complex adaptive systems may have only a few simple rules guiding them to determine change, patterns can become apparent over time. When patterns between variables emerge, they are called attractor states in the system, so that at any moment a complex system is either flowing to or maintaining an attractor state (Handford, Davids, Bennett, & Button, 1997). Since complex systems are so sensitive, a seemingly inconsequential change in one factor may modify the behavior of the entire system. Complexity science is positioned in neither order/determinism, nor disorder/chance and probability (Axelrod & Cohen, 2000); it is a science of patterns, or attractor states. Complex patterns of non-linear interactions are difficult to predict but not random. These systems display complex interdependencies where small actions may net large consequences. Such a change is termed a bifurcation and moves a system from one attractor state to another.

Bifurcation points are critical points of instability within a system (Capra, 2002). Systems are deemed unstable when attractor states change, disappear, or new ones suddenly appear. Small inputs may cause such a shift in complex adaptive systems, and the bifurcation point is apparent as a new attractor state emerges after a sudden change in the system. At these bifurcation points, new forms of order spontaneously emerge in systems; change is abrupt (Capra, p. 23).

A caveman creates a wheel; a chimpanzee uses a stick as a tool. How many times do we imagine our understanding of turning points of groups or civilizations based upon the tools that they use? Society again has new tools to utilize as it proceeds into what has been termed the information age, a time that began within approximately ten years of 1990, "in which information and communications will become the dominant forces in defining and shaping human interactions, activities, and institutions" (Alberts & Papp, 1997, p. 13). These tools establish the educational system's most recent set of initial conditions that will catalyze and help form the next iteration of public education. The effect of the Information Age on formal education cannot be forecast, but should be considered as we grapple with the paradigmatic shift.

Complexity and change are the two defining characteristics of the Information Age. Our successes as individuals, families, organizations, communities and societies will depend more than ever upon our abilities to adapt, in near real time, to deal with increasingly complex and dynamic situations which will be characteristic of the Information Age. (Alberts & Papp, 1997, p. 6)

"Ultimately, we imagine the information age in order that we can affect its becoming" (Lallana, 2003, p. 5). As we imagine this becoming in the realm of education, it is important to consider the new tools that may be shaping societal change, as well as the generational shift that has occurred as a result of the Net Generation, students of the Information Age. Often, metaphor is used to better understand conceptually challenging ideas and to guide learners to profound realizations. Complexity science can be applied to education in this way.

COMPLEXITY AS A METAPHOR IN EDUCATION

An abrupt change is now upon the educational system, and complexity science provides a new way of understanding systems' changes when the discipline is used as a metaphor. Complexity science may be seen as a powerful metaphorical tool providing a lens through which to see organizations (Richardson & Cilliers, 2001). An example of such a complex emergence is the classroom collective, an oft-overlooked complex adaptive system that consists of learners cohering into a "unit of cognition whose capacities exceed those of the individuals on their own" (Davis & Sumara, 2005, p. 315). Working from the notion that human organizations like schools can be understood as complex systems, we can then investigate them through the terms of complexity science including initial conditions, attractor states, and bifurcation.

As with weather, the initial conditions of the American educational system have played a major role in realizing its present form. The colonies began formalized education in a manner that set the stage for today's system. Early American students began their schooling at home but as populations grew so did the existence of regional schools. These schools began where space could be found in spare rooms, barns, and halls. Then through the land ordinance of 1785 President Thomas Jefferson and Congress designated land in every township for a public school (Morris & Morris, 1996). Rural areas with sufficient numbers of students and support built schools for kindergarten through grade eight. Since no previous American models existed to copy, one-room schoolhouses emerged as meeting the needs of these areas. Desks and blackboards were not a part of the classroom until the 1820s as schools grew to meet the needs of the community (Barger, 2004). Usually, one teacher taught basic skills and content, such as arithmetic, reading, penmanship, spelling, geography, and history, to all non-graded age levels, both boys and girls. This teacher was responsible for all of the administrative and teaching loads, as well as other daily duties in the school including shoveling snow, keeping the schoolhouse warm by obtaining firewood, stoking the stove, and bringing in water from outdoor wells (Library of Congress, ND).

Early on, multi-age student groups remained ungraded. The learning community expected more advanced students to help lower-level and struggling students. Older students were the only assistants that teachers knew, support staff being non-existent. Segregating students by age began in the mid-1800s as an efficiency response to the large number of immigrant students that required schooling (Gaustad, 1992). This practice of graded education, where students are classified and divided by age, continues today. As the population grew, educators embraced an industrial notion of schooling en masse, a factory model where students were graded and expected to move along at the same pace by grade level. This model was a result, in part, of the need for efficient, economical systems capable of handling large numbers of students. As form followed function, two-story schools were built to accommodate the different classes. Later, entire campuses would emerge as schools

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added gymnasiums, laboratories, libraries, administration offices, and departmental teaching spaces. VanMaanen (as cited in Schein, 2004, p. 163) maintained that these spaces have both physical and social meaning through which educational organizations transmit values and assumptions. Implicit in these assumptions are the linear Newtonian notions of predictability and certainty as students are moved through the structure of the building from one grade to the next in regular progression.

ATTRACTOR STATES – PATTERNS IN EDUCATION

Many of the characteristics described above continue to be seen in schools today. According to Meyer and Rowan (as cited in Bolman & Deal, 2003) the structure of American public schools is highly symbolic and resistant to change. In order to generate and maintain public support schools must have the proper answers to the communities' questions. These answers include appropriateness of the subjects taught at the school, an age-graded structure, teachers who are appropriately certified, and the respectable appearance of the school, preferably "with classrooms, a gymnasium, a library, and a flag near the front door" (Bolman & Deal, 2003, p. 274). The basic assumption that this particular combination creates a school leads to educational structures that are "nonconfrontable and nondebateable, and hence extremely difficult to change" (Schein, 2004, p. 31). In practice, these space-time realities have functioned as attractor states for the educational system. Buses move around them, but are confined by geography that, in turn, dictates scheduling and design. A remnant of an agrarian past is the scheduling attractor based on the agricultural year, in which school calendars are planned around the growing season in order to provide students time for harvest, an important symbol of a previously agrarian economy. So attractor states that currently characterize American education include student grouping, architectural and instructional design, and scheduling. An awareness of these states is essential as educational leaders work within a system that has reached a bifurcation point.

BIFURCATION – THE GENERATIONAL TIPPING POINT

As argued above, if human systems have similar properties to complex adaptive systems then small changes may lead to an abrupt shift from one attractor state to another. A change upon the educational system that might motivate such an abrupt shift includes the most recent generation of students to go through schools. The Net Generation includes students born between about 1980 and 1994 (Carlson, 2005) who exhibit different expectations, styles, and preferences than earlier generations. This generation is the mass behind the grass-roots movement, intentional or not, to change schools, particularly high schools. This generational bifurcation might motivate the current American educational system to examine its current attractor state in space-time versus more complex versions that better serve the learners' needs. Adapting to this change in stakeholders will require a change in educational leadership reflected in the metaphors of complexity science.

Changing the notion of how and where learning can take place, and embracing a new paradigm of teaching, may be inevitable as educators experience identity created in interaction. For learners, this interaction may happen in the classroom as well as outside of it. Often a classroom of learners attains its own interactive identity unique from any of its individual participants (Davis & Sumara, 2005). "The demise of the classroom itself is not far behind" (Siemens, 2007, p. 2). Educators will focus less on designing content and more on creating the space, or context, of learning as they embrace these new understandings of learning. Siemens maintains that preparing for complex, rapidly changing environments means more attention must be paid to the design of the space, as it carries more influence there than in static environments.

SHIFT HAPPENS

A change from this static state to a more responsive, engaged one might require a shift in thinking. When we cite "scientific thinking," we still refer to Newtonian paradigms. A worldview that springs from such linear thinking is based on reductionism, determinism, and objective knowledge, its appeal resting in its "simplicity, coherence, and apparent completeness" (Heylighen et al., 2006, p. 3). Ideas from Newtonian science are often confirmed by intuition and common sense (Heylighen, et al., 2006). These ideas support a perspective that embraces a logic based upon reductionism. Complex phenomena are commonly broken into parts; this is repeated in order to look at the components for understanding of the bigger piece. Larger concepts can be understood by knowing their smaller components. This distinction of parts through observation is absolute and objective, insisting upon a consistent reality for all observers. Such a view creates perceptions of reality maintaining that we can objectively know, measure, and predict. These qualities suppress uncertainty and give the knower a sense of power as one outside of the system, able to manipulate it at will. However limited, this sense may be even less applicable in the education arena.

For example, Siemens suggested that design be less structured in advance of the learning, and more involved once it has begun (2007). Focusing on creation of the learning space takes priority over designing a program for learning content. This learning space is where educational leaders can make some of the first changes to acknowledge complexity in the educational system, and to better serve the learners' needs. Before such change will be realized, old conceptions of leadership will be amended as metaphors from complexity science enter the public domain and new perspectives are appreciated.

This relational, participation-based perspective that emerges from the metaphors of complexity science may hold additional attraction for us because of "our changing conception of the organizing principles of the universe" (Wheatley, 1992, p. 143) and because the Net Generation has provided a point of no return to the old ways of teaching and learning. Using complexity science as a metaphor may lead to a greater understanding of what educational leaders can create as their perceptions of the role of an educational leader shift. As these leaders strive to improve schools, understanding the educational system as a complex adaptive system with initial conditions, attractors, and bifurcation points is an important part of embracing systemic change through the lens of complexity.

WHAT NEXT?

Pursuing educational change through a lens of complexity lends itself to at least two considerations for further research on policy and educational design (Siemens, 2007). First, educational leaders would reframe conceptions of teaching and learning to see instructional design as part of the learning process instead of as a task that occurs prior to the intended learning. Second, educational leaders would intentionally focus on the context of learning, designing environments of learning, more so than particular learning activities. This learning context becomes the new space of learning and includes the environment, circumstance, and events that impact a learning activity, program, or project. Siemens also stated that aligning the elements of a learning context is crucial, and these include the space of learning, attributes of the learner, the nature of the learning experience, trainer experience, and types of content, technology, assessment, and support. As these elements are attended to, schools may begin to see new formats and spaces, physical and virtual, for implementing school change as we move together into the Information Age.

As overwhelming as conceptual change seems, it can be glimpsed as we apply new frames to old pictures. This can be done through any of the attractors, but consider architecture as a place to start. Envision the learning space in which you work, from the building right on into the classroom. What paradigm does this space reinforce: a linear, mechanistic, Newtonian understanding, a complexity perspective, something in-between? How is the design of the space guiding the teaching and learning that

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occurs within? Do the building's attributes affect scheduling and student grouping? If so, how? If it is true that "We shape our buildings and after-ward our buildings shape us," as said by Winston Churchill of the bombed Houses of Parliament and their influence on democratic institutions, considering a structure as an "object of human agency and as an agent of its own" (Gieryn, 2002, p. 36) may facilitate a new way of thinking about the space and process of learning. While complexity poses even larger conceptual challenges, this may be the place for educators to begin their journeys towards understanding schools in new ways.

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