ADVANCES IN CREATIVITY AND GIFTEDNESS

A Critique of Creativity and Complexity

Deconstructing Clichés

Don Ambrose, Bharath Sriraman and
Kathleen M. Pierce (Eds.)

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A Critique of Creativity and Complexity

ADVANCES IN CREATIVITY AND GIFTEDNESS
Volume 7

Advances in Creativity and Gifted Education (ADVA) is the first internationally established book series that focuses exclusively on the constructs of creativity and giftedness as pertaining to the psychology, philosophy, pedagogy and ecology of talent development across the milieus of family, school, institutions and society. ADVA strives to synthesize both domain specific and domain general efforts at developing creativity, giftedness and talent. The books in the series are international in scope and include the efforts of researchers, clinicians and practitioners across the globe.

A Critique of Creativity and Complexity

Deconstructing Clichés

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In the last decade the words “creativity” and “complexity” have proliferated in the learning sciences, the organisational sciences, economics, education and the humanities to the extent that they almost sound clichéd. School systems, policy documents, funding bodies and scientific foundations repeatedly invoke creativity and complexity in vision/mission statements and calls for research proposals. This has generated some benefits and problems. One of the benefits is the invigoration of interdisciplinary work pertaining to complex phenomena that cannot be understood from within the borders of insular disciplines. A drawback is the occasional misinterpretation of the nature and nuances of complex, adaptive systems. In this book, researchers and theorists from various disciplines critically examine disciplinary boundaries in relation to the terms “creativity” and “complexity” with the goal of moving beyond clichéd uses of these constructs. The book also includes chapters that apply concepts from complexity theory and creativity in a practical sense.

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SECTION 1

INTRODUCTION

DON AMBROSE

CREATIVE EMERGENCE, ORDER, AND CHAOS: GRAPPLING WITH THE COMPLEXITY OF COMPLEXITY THEORY

Complexity theory encompasses promising, interdisciplinary attempts to understand the complex dynamics of exquisitely interconnected, dynamically evolving systems. In today's increasingly complex, turbulent world, excessively simplistic, reductive approaches to theory development, research, and practical application increasingly come up short when applied to complex problems. Fortunately, complexity theory can provide helpful correction, overriding the dogmatism that ensues from shortsighted, superficial explanations of nettlesome phenomena. Nevertheless, given its intricacy, attempts to understand and apply complexity theory also can fall prey to dogmatic misconceptions. The chapters in this volume represent insightful attempts to correct some of these misconceptions while finding ways to apply complexity theory to problems and opportunities in transdisciplinary work, general education, STEM education, learner diversity, social-emotional development, organisational leadership, urban planning, and the history of philosophy. More opportunities for creative thought and action in these domains arise from the analyses.

THE DUAL-EDGED SWORD OF SIMPLISTIC REDUCTIONISM

There is growing recognition that reductive treatments of complex phenomena have enabled considerable progress, especially in the natural sciences, while also leading us into dead ends. For example, in a sweeping, interdisciplinary investigation of complexity, leading thinkers from a wide variety of fields recently grappled with the tension between the need to simplify phenomena and the need to recognise and embrace complexity. The editors of the volume explained:

> The spectacular progress in particle and atomic physics, for example, comes from neglecting the complexity of materials and focusing on their relatively simple components. Similarly, the amazing advances in cosmology mostly ignore the complications of galactic structure and treat the universe in a simplified, averaged-out, approximation. Such simplified treatments, though they have carried us far, sooner or later confront the stark reality that many everyday phenomena are formidably complex and cannot be captured by traditional reductionist approaches. (Lineweaver, Davies, & Ruse, 2013, p. 3)

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 3–15.

These warnings about excessive reductionism came from a group dominated by natural scientists including leading thinkers from astrophysics, biology, evolutionary paleobiology, cosmology, physics, astronomy, mechanical engineering, and the philosophy of science, among others.

Similar cautions arise in other disciplines. For example, economics is extremely influential in our everyday lives because it underpins the workings of our financial system, and of globalised capitalism more generally. However, there have been vigorous criticisms of the rational actor model that dominates standard, neoclassical economic theory (see Ambrose, 2012a, 2012b, 2012c; Konow & Earley, 2007; Madrick, 2011; Marglin, 2008; Schlefer, 2012; Stiglitz, 2010, 2012; Stiglitz, Sen, & Fitoussi, 2010). The excessively sanitised, hyper-reductive model portrays humans as highly rational beings who make solely self-interested decisions based on perfect information sets. The model works well as a driver for empirical and theoretical work in economics but it doesn't map onto the world very well because the typical human injects considerable irrationality into his or her decision-making, is not entirely self-interested (unless he or she is a psychopath), and rarely has access to anything near a complete set of information for complex decisions. Arguably, the inadequacies of this oversimplified theoretical model contributed strongly to the 2008 economic collapse and to other serious, high-impact economic distortions.

Behaviorism, which dominated psychology in the mid-20th century, represents another example of temporarily productive but excessively sanitised, reductive theory. The behaviourist framework exiled the nettlesome complexities of the mind (anything that could not be measured with precision) to confinement within a metaphorical, cranial black box in attempts to mimic the hypothetico-deductive precision of empiricism in the natural sciences. The paradigm generated progress in psychology but eventually led theorists and researchers into increasingly barren territory. This led to its replacement by cognitive science—an energetic but still flawed new paradigm that was open to more diverse investigative methodologies and more authentic theoretical portrayals of the brain-mind system (see Ambrose, 2003, 2009a).

In yet another example, Bleakley (2010) made the case that effective medical education requires more tolerance of the ambiguity that arises from the complex, dynamic biological and technical systems medical practitioners repeatedly confront in their work, and that this tolerance can arise from capitalising on team learning. The distributed cognition that can arise from ambiguity embracing teamwork can enable medical professionals to diagnose and treat more effectively; however, the dominant model of medical education works against understanding of complex, adaptive medical systems because medicine is ideologically grounded in notions of excessive individualism and the acquisition of discrete knowledge elements.

TRAPPED WITHIN METAPHORS

These rigid theoretical frameworks arise from dogmatic entrapment within one of several root-metaphorical world views. The prominent philosopher Stephen Pepper

(1942) analysed deep-level influences on human thought and action and categorised these influences into world hypotheses, which included mechanism, organicism, contextualism, and formism. As scholars later used these frameworks for analyses of phenomena in various disciplines, the world hypotheses became known as world views (see Ambrose, 1996, 1998a, 1998b, 2000, 2009c, 2012b, 2012d; Cohen & Ambrose, 1993; Dombrowski, Ambrose, Clinton, & Kamphaus, 2007; Gillespie, 1992; Heshusius, 1989; Overton, 1984; Terry, 1995). Each world view is rooted in a metaphor that implicitly shapes thought and action. Each root metaphor structures the development of philosophical, theoretical, methodological, and practical tenets that guide the work of academics and professionals. All of this occurs at very deep, implicit levels and thinkers rarely are aware that their minds are trapped firmly, even dogmatically, within a metaphor.

As with peeling away the layers of an onion, we can peel away layers of implicit conceptual influence to get down to the root metaphor that simultaneously makes us somewhat effective as theorists, methodologists, or practitioners, but also somewhat ineffective because the metaphorical entrapment prevents perception of other options. For example, mid-20th century teachers who excessively used reward and punishment to manipulate their students' actions may not have realised that they were guided by the advice of psychologists whose thoughts were dominated by behaviourist theory. Many if not most of those psychologists did not realise that the behaviourist theory shaping their work was rooted in the positivist research paradigm. Many philosophers of science who promoted positivism likely did not realise that their philosophical framework was rooted in the mechanistic world view.

This lack of awareness that our thought is rooted down through multiple levels of analysis illustrates one of the strongest reasons for the ubiquity of dogmatism in human thought and action. Dogmatic idea frameworks force us to think more superficially, narrowly, and in more shortsighted ways than we should (for more on dogmatism see Ambrose, 2009b; Ambrose, Sternberg, & Sriraman, 2012; Ambrose & Sternberg, 2012). Table 1 shows the four world views, their root metaphors, the conceptual tenets that emerge from the metaphors, and examples of influences each world view has exerted in academia.

While a very simple system such as a simple machine can be investigated effectively through the lens of a single world view, complex systems nested within complex, multi-layered contexts are far too intricate for us to understand through a single conceptual lens, hence, we see the dogmatic folly of excessive adherence to the rational actor model in neoclassical economic theory, or the behaviourist model of mind in mid-20th century psychology. Pepper (1942) metaphorically illustrated the need for navigation through multiple world views:

> Post-rational eclecticism is simply the recognition of equal or nearly equal adequacy of a number of world theories and a recommendation to not fall into the dogmatism of neglecting any one of them. . . . Four good lights cast fewer shadows than one. (p. 342)

Table 1. Root-metaphorical world views as alternative conceptual frameworks for investigation of complex phenomena.

World View	Root Metaphor	Basic Tenets (what the world view emphasises)	Examples of Influence in Academia
Mechanism	Machine	Reduction of the whole to its component parts; precision; detail; linear causality; objectivity	Psychologists reducing intelligence to a precisely measurable IQ score
Organicism	Organism developing through stages toward a particular end	Coherence and totality of systems (the whole transcending its parts); integrative connections; long-term development	Interdisciplinary work (integrating knowledge across disciplines); much theorising about child development
Contextualism	Ongoing event within its context	Contextual influences; unpredictable emergence of novelty	Cognitive scientists studying the context-embedded mind (contextual influences on thought patterns)
Formism	Ubiquitous similarity (e.g., Plato's ideal forms)	Search for patterns of similarity in diverse phenomena	Complexity theorists studying patterns of similarity in the dynamics of complex adaptive systems such as human brains, national economic systems, fractal mathematics

Given the increasing recognition of the intricate complexity in complex adaptive systems, these four good lights are needed now more than ever before. Complexity theorists have revealed a wide array of baffling phenomena that show up as patterns in exquisitely complex systems (see Anteneodo & da Luz, 2010; Bleakley, 2010; Boedecker, Obst, Lizier, Mayer, & Asada, 2012; Chen, 2010; Fontdevila, Opazo, & White, 2011; Gershenson, 2012; Kelso, 1995; Lizier, 2012; Mazzocchi, 2012; Miller & Page, 2007; Morowitz, 2004; Schneider & Somers, 2006; Watts, 1999). For example, the innumerable elements of a complex, adaptive system can spontaneously self-organise into intricate, beautiful, and evolutionarily advantageous patterns. The dynamic tension between frustrating chaos and stultifying order can give rise to productive complexity. Also, intriguing behavioural and structural similarities can be seen in very diverse complex systems.

Understanding complex, adaptive systems brings to mind the old Sufi parable of the blind men and the elephant. Similar to the blind men in the fable, an investigator employing the conceptual lens of a single world view might grasp a seemingly crystal-clear glimpse of a portion of the behaviour and evolving structure of a complex adaptive system, such as a creative individual, but could never hope to understand it in its entirety. For example, a mechanistic neuroscientist can clarify the electrochemical communication processes within a neural network within the brain of a creative person but will have great difficulty perceiving the ways in which those neural networks are influenced by subtle changes in other biological subsystems within the body, or by minor shifts in the environmental context that influence the person who owns that brain. A contextual mind theorist would have a better chance to understand environmental influences but would lack the precision and clarity provided by the mechanistic researcher who reveals insights about the electrochemical processes. Moreover, the long-term developmental perspective provided by an organicist developmental psychologist who looks at creativity as an integrative, lifetime process instead of an instantaneous light bulb moment of inspiration (e.g. Gruber, 1989) also is necessary to understand the creative work of the individual in its totality. The more perspectives from diverse disciplines that can be brought together and synthesised, the better, although such synthesising admittedly is a daunting challenge.

While it likely is impossible for a group of theorists and researchers to gain anything near complete understanding of complexity and creativity, an ambitious group can make some progress toward that goal. Our collaborators in this project recognise the intricacies involved in wrestling with the nuances of complex adaptive systems. The composition of our investigative team reflects this recognition. We include theorists, researchers, and professionals from diverse disciplines. Our collective expertise encompasses dimensions of gifted education, creative studies, educational philosophy, mathematics and the sciences, English literature, the history of philosophy, urban planning, and interdisciplinary work. Consequently, the contributors to this volume have shed some illumination on complex creativity by employing Pepper's (1942) four good lights.

AN OVERVIEW OF THE CONTENTS IN THE VOLUME

The first section of the book applies various constructs from complexity theory to teaching and learning in mathematics and the sciences. In recent years policymakers, citizens, and educators have paid considerable attention to the need for, and enhancement of, STEM expertise. Unfortunately, shortsighted educational reform initiatives preempt the development of complex understanding and higher-order thinking throughout the K-16 curriculum, including in the STEM disciplines (Berliner, 2006, 2012; Ravitch, 2010, 2013). Our contributors in this section suggest some ways to reinvigorate STEM complexity.

Bernard Sarrazy and Jamilla Novotna show how complexity theory can be employed to explore the creative versus reproductive dimensions of mathematics education in their chapter, *Learning: Creation or Re-creation? From Constructivism* *to the Theory of Didactical Situations.* They analyse studies of conditions and processes conducive to creative learning within complex contexts. More specifically, they reveal in-depth analyses of developmental dynamics and the ways in which those dynamics can include emergent properties based on complex pedagogical and creative interactions. Essentially, the teaching of mathematics entails the artful establishment of promising conditions for the emergence of creative mathematics understanding. Ultimately, they show that there should be less interest in creation as such than about pedagogical and didactical conditions conducive to its emergence in mathematics learning. The mission of mathematics educators should be to create environmental contexts that enable mathematical creativity.

In her chapter, *Investigating Mathematical Creativity in Elementary School Through the Lens of Complexity Theory,* Esther Levenson used results from empirical observations in classrooms in the city of Tel Aviv, Israel to analyse dynamics of mathematics learning through the lens of complexity theory. Focusing on student interactions with materials, other students, and teachers, Levenson discovered ways in which ideas emerged and were developed. She found that creativity, as it is manifested in the classroom, entails complex, unpredictable, mutual adaptation of all players within the complex adaptive system of the classroom. On the one hand, the teacher and the students are all present in the same lesson and there is a collective experience. On the other hand, different individuals experience instruction in different ways. This chapter outlines the dynamic interaction and interdependence of classroom participants, as well as the tension between pursuing both stability and change. In essence, the author explains how the results of these swirling forces and some principles of complexity (i.e., internal diversity, redundancy, decentralised control) can promote or inhibit mathematical creativity.

Steve Coxon, takes us into an intriguing aspect of science and technology with his chapter titled *On the Edge of Chaos: Robots in the Classroom.* He begins by discussing the role of robots in our world and then turns to the value of robotics as a learning opportunity. Coxon does this by contrasting the processes of robotics with the structure and dynamics of traditional education. He describes the history and nature of educational robotics programs and outlines a variety of current robotics offerings. While making it clear that robots are nowhere near as complex as biological systems, he argues that they allow for enormous cognitive complexity when it comes to students building and using them. He keeps us informed about the research into the effectiveness of robotics as an educational strategy. He also establishes some similarities between large-scale political-democratic dynamics on the edge of chaos and the instructional and learning processes in robotics. Learning is much more dynamic and productive at this edge where there is balance between orderly, authoritarian control and anarchic chaos.

In recognition of the strong, interdisciplinary nature of scholarship addressing complex adaptive systems our next section brings together interdisciplinary perspectives on creative complexity. Here we include a broad survey of complexity theory in multiple disciplines as well as more specific applications to organisational leadership, environmental sustainability, and urban planning.

Don Ambrose employs a specific construct from complexity theory to generate a very broad-scope exploration in the chapter, *The Ubiquity of the Chaos-Order Continuum: Insights from Diverse Academic Disciplines.* The interdisciplinary science of complexity is revealing ways in which complex adaptive systems tend to oscillate along a continuum between the extremes of chaos and order. Productive, creative complexity occasionally becomes available when a fine balance emerges from the tension between chaos and order on the continuum. While there is some potential for misinterpretation of this construct, the dynamics of the continuum are applicable to a wide variety of phenomena. This interdisciplinary analysis reveals some ways in which excessive order, excessive chaos, and productive complexity can emerge in human thought and action. Some examples include the tensions between relativism and authoritarianism in identity formation and moral development; laissez-faire market utopianism and centralised regulation in economic systems; relativistic pluralism and universalist monoculture in the culture wars; anarchy and rigid, scientific management in organisational dynamics; incremental wandering and the lure of completeness in the philosophy of science; and the fractured-porous and unified-insular structure and dynamics of academic disciplines. Thematically guided interdisciplinary exploration, dialectical thinking, and the logic of the included middle are proposed as antidotes to entrapment within the counterproductive regions of the chaos-order continuum.

In her chapter, *Creative Complexity in Organisational Leadership,* Liza Watson discusses creativity and learning in organisations and some ways leadership comes into play in these dynamics. Leadership theories are considered in light of the dynamics of the chaos-order continuum. Watson also contemplates these leadership dynamics while analysing their fit with the industrial age that we are leaving and the knowledge era in which we are currently immersed. In essence, these dynamics revealed by complexity theory can be difficult for individuals and organisations to handle because they can be disruptive even while they provide opportunities for creative organisational progress.

Marna Hauk argues that priorities must change if the world is to shift from degenerative environmental destruction to regenerative sustainability. In her chapter, *Complex Regenerative Creativity,* Hauk shows that predominant analytic and deterministic methods usually provide knowledge of parts and mechanisms, but they rarely yield adequate answers. Creativity enters the process in the key role of assembling diverse parts, often in unexpected ways. Regenerative design involves both art and science not separately but merging together. The theoretical framework in this chapter employs complexity theory emphasising regenerative creativity as domain-general and transdisciplinary in nature. The framework produces ethical novelty inspired by complex, natural patterns.

Todd Juhasz illustrates the broad applicability of complexity theory in his chapter, *Pareto Optimum Efficiency Between Chaos and Order when Seeking Consensus in Urban Planning.* Based on his experience as an urban planner with transdisciplinary expertise encompassing the biological sciences, architecture, and management, Juhasz establishes a comparison between two case studies of major urban planning projects in two important American cities, one on the East Coast and one on the West Coast. One of these projects suffered from frequent, serious problems and was completed with minimal success. The other project proceeded with fewer problems and led to very successful outcomes. The comparison reveals that successful urban planning and implementation requires artful negotiation to keep the process from disintegrating toward excessive chaos or becoming trapped within excessive order. In contrast, careful, artful urban planning generates a productive balance between chaos and order, which leads to complex yet effective results. Recommendations for the education of students in the urban planning profession are provided.

Rounding out this exploratory, interdisciplinary section, Peter Pruim takes us on a philosophical excursion in his chapter, *Subjectivity, Objectivity, and the Edge of Chaos.* His analysis has two stages. First, he uses the of edge-of-chaos heuristic to classify general epistemological positions. At the extreme of order are the epistemology of the Rationalists and all irrational ideologies where no experience is allowed to count against fundamental principles. At the extreme of chaos are various forms of radical empiricism, including positivism, where reality is identified with experience, which is ever changing and different for every observer and so generalisable theorising is difficult. At the edge of chaos is the sort of empiricism promoted by Quine and Susan Haack, in which the two dogmas of empiricism are replaced by balancing theoretical coherence with observational adequacy. In the second stage of the analysis, Pruim uses this heuristic to describe the history of philosophy of mind: Cartesian dualism, materialist identity theory, materialist functionalism, eliminativism, Wittgenstein and behaviourism, neurophilosophy, and the current scene in cognitive science.

The next section of this book returns us to the nature and nuances of the educational system. It begins with a philosophical analysis of educational purposes and processes. After that, we include more specific insights about the promise of complexity theory in education, from the tension between modernism and postmodernism in diverse forms of expression, to the creativity it reveals in a project blending Shakespearean literature and the performing arts, to the promise of dual exceptionality as a creative advantage, to creative mentorship of new professionals as they make their way into complex work environments.

In their chapter, *Expansive Notions of Coherence and Complexity in Education,* Bryant Griffith and Kim Skinner argue that our culture is embedded within a dynamic tension between coherence and complexity, and that tension generates conceptual chaos. Griffith and Skinner employ complexity theory as a tool for critiques of the excessively mechanistic approaches that dominate education today. They bring into play conceptions of modernism and postmodernism while looking at ways in which human interactions and context tend to be ignored and marginalised. It is these interactions and contextual influences that enliven education and make it too complex for mechanistic approaches alone to handle. Appreciating and capitalising on epistemological diversity is a theme in the chapter. The authors make room for various forms of cognitive diversity, including domain-specific cognitive frameworks. They also use research findings to illustrate ways in which students can be encouraged to engage in higher-order thinking conducive to complex understandings of text.

Jeffrey Bloom provides a panoramic overview of analyses of complexity in diverse phenomena in his chapter titled *Complexity, Patterns, and Creativity.* Deriving insights from the history of creativity research and from extensive investigations of complex adaptive systems, Bloom uses this analysis as a basis for considering ways in which creativity emerges and complex patterns form. He pays special attention to scientific phenomena, especially the formation and utility of meta-patterns that underpin and sustain the structure and function of complex systems throughout nature. Implications for education arise from the analyses. Especially pertinent are his recommendations for preserving creativity in learning, and for developing a stronger grasp on the pernicious effects of superficial, dogmatic school reform initiatives such as No Child Left Behind and the Common Core standards.

Kathleeen Pierce provides an example of socially generated, emerging complexity in her chapter, *A Shakespeare Festival Midwives Complexity.* She explains how preparation for participation in a Shakespeare festival performance creates a community of practice among secondary school students who work along the chaos-order continuum. Procedures employed in the management of the festival seem to provide just the right amount of constraint to nurture complex thinking without inhibiting students' creativity in interpreting Shakespeare and designing an original 20-minute performance from his plays. The festival day itself provides a series of workshop sessions in theatre arts where students quickly learn new skills, play, and practice in the company of students from other schools. The festival design imposes order and allows for chaos in each of the workshops before complexity emerges in the form of new competencies developed in collaboration with new acquaintances.

Jack Trammell has us think about an issue that straddles the fields of gifted education and special education in his chapter, The Anthropology of Twice Exceptionality: Is Today's Disability Yesterday's, or Tomorrow's, Evolutionary Advantage? A Case Study with ADD/ADHD. Some anthropologists and psychologists suggest that the ADD/ADHD arrangement of the prefrontal cortex may have been an evolutionary advantage 20,000 years ago when humans had a greater need to respond rapidly to stimuli in the environment and to consider creative, nonlinear approaches to problem solving. In today's world, that same brain arrangement is often treated as a disability and the potential giftedness associated with it is overlooked. Trammell briefly examines the historical etiology of ADD/ADHD, considers current neuroanatomical perspectives, and suggests that the degree to which the brain arrangement is considered medically disabling is problematic. He then shows how conceptions of

ADD/ADHD as a disability are being transformed. Finally, he proposes that the concept of twice exceptionality itself actually may be a misinterpretation of a rapidly evolving human brain in which today's disability can be yesterday's, or tomorrow's, special ability.

In the chapter, *Mentoring the Pupal: Professional Induction Along the Chaos-Order Continuum,* Kathleen Pierce employs the chaos-order continuum again, this time to analyse the difficult problems beginning professionals face when making the transition into a complex profession. She shows how beginners in schools and universities often have great problems adjusting and getting up to speed with highly complex professional demands even though those institutions often have established formal mentorship programs. Thinking about the ways in which these experiences oscillate along the chaos-order continuum helps us see how the immense difficulty arising from rapid immersion in highly complex, multilayered processes and contexts establishes chaotic conditions in the beginner's mind while the excessive order of the bureaucratic procedures typical of induction processes represents excessive order on the continuum. According to Pierce, nuanced mentorship can enable beginning professionals to find a productive balance between these extreme conceptual positions where they can begin to enjoy the fruits of professional complexity.

Our final section provides a look at the social-emotional dimensions of complex creativity. There is increasing recognition that high-level cognition incorporates emotional ingredients, especially when it comes to creative work. These emotional ingredients can be injected through the influence of productive relationships, recognition of the need for cognitive restructuring and integration, and awareness of barriers that can distort the emotional elements of thought.

Michelle Jordan and Reuben McDaniel emphasise the importance of social dynamics in their chapter, *Helping Students Respond Creatively to a Complex World.* They begin by taking aim at the persistent dominance of conceptual frameworks saturated with scientific determinism when it comes to influence over educational philosophy and practice. After addressing that pressing issue they posit knowledge of complex adaptive systems as an alternative framework. They go on to explain how this alternative reveals dynamic complexity in a wide range of phenomena pertaining to education and creativity. They also provide advice about how to help students navigate the contextual intricacies revealed by their analysis. Some of this advice includes developing ways to help young people tolerate and embrace the fundamental uncertainty of complex environments while capitalising on the potential embedded in dynamic relationships. Jordan and McDaniel also provide a wide variety of examples of practical, creative strategies that can be used in classrooms to generate better understanding of system dynamics.

In her chapter, *Toward the Pattern Models Of Creativity: Chaos, Complexity, Creativity,* Krystyna Laycraft provides a new approach to the study of creativity in adolescents and young adults engaged in complex, creative endeavors by combining the idea of self-organisation with theories of emotions. Employing qualitative research methods she found some differences in the creative work of young people, but also discovered common phases such as differentiation/chaos, integration/complexity, and dissipative structures/creativity (products of creativity in the forms of new movements, new writings, and new paintings). Creativity of the young people under study was intertwined with strong emotions of interest, joy, and acceptance. These dynamics encouraged global, open, and exploratory modes of attention, stimulated thinking, and enriched imagination. All of this deepened emotions, leading to more curiosity, enthusiasm, delight, passion, resourcefulness, and love. Creative individuals became more sensitive, more open, and receptive to their internal and external worlds. They seemed to become more resourceful, imaginative, empathic, and spiritual.

Ann Gazzard concludes this section, and the volume, with her chapter, *Emotions, Complexity, and Intelligence.* She shows how the edge of chaos hypothesis from complexity theory can elucidate our understanding of emotional intelligence, in particular its foundation in the early childhood years. She draws insights from psychology, neuroscience, and other fields to shed light on the complex dynamics of emotional development and barriers that suppress or distort that development. Based on syntheses of these insights, she concludes with recommendations for enhancing and strengthening emotional intelligence in young children.

While our motley coalition of investigators from multiple academic and professional fields has employed analytic insights from Pepper's (1942) four good lights, we certainly have not covered all of the conceptual territory relevant to the nature of complex adaptive systems. That territory simply is far too expansive to grasp in a single project and much more can be done in future investigations. Others have developed important insights about the creativity-complexity theory nexus (e.g., Richards, 2001, 2010; Schuldberg, 1999; Sterling, 1992) and we hope that our project augments their work. Our primary purpose has been to expand awareness of the promise and intricacies of the meeting place between complexity theory and creative effort. We encourage future development of theory and research along these lines.

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SECTION 2

COMPLEXITY IN STEM PROCESSES AND STRUCTURES

JARMILA NOVOTNA & BERNARD SARRAZY

LEARNING: CREATION OR RE-CREATION? FROM CONSTRUCTIVISM TO THE THEORY OF DIDACTICAL SITUATIONS

> The mere fact that the result of original work in the mathematical field is called sometimes a *creation* or *invention*, sometimes a *construction* or *discovery*, shows all the multiformity of mathematical experience.
>
> J. Piaget and E.W. Beth (1974)

> It is indispensable that every teacher, every day, begins his/her class as if the knowledge that he/she proposes to students were discoveries for the first time in the world and as if this meeting was decisive for … the future of mankind.[1]
>
> G. Brousseau (1986)

INTRODUCTION

The idea of the child "creator" is historically associated with its activity and with "construction" of connaissances and savoirs[2]. These ideas developed within pedagogical streams, namely in active pedagogy, and their boom was brought about with the emergence of constructivism especially with Piaget. In fact, Piaget's theory triggered a fundamental breakdown in the conceptions of learning seen as adaptation to the environment and of knowledge seen as a dynamic process of adaptation between the subject's schemes and the object of the knowledge. Despite the fact that constructivism significantly influenced teaching and learning, the theory did not enable pinpointing of the conditions under which a situation becomes a didactical situation with didactic properties; an error is constructive for new knowledge only through the regulations that enable its avoidance. Application of this theory in teaching and learning (Aebli, 1966) led to reinforcement of the idea that the child is the "creator." Constructivism also led to the belief in the inevitability of the development of logical-mathematical reasoning and therefore of the student's mathematical mind independent of teaching/learning situations as such. But descriptions of cognitive processes in Piaget do not enable us to study and define the didactical conditions that enable us to carry out these processes. This became the object of the first theorisation of didactical phenomena at the end of the 1960's (Brousseau, 1997).

The properties of these situations can be derived neither exclusively from the student (the epistemic subject) nor exclusively from mechanisms of their pedagogical

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 19–33.

limitations. Nor can they be derived only from the examination of knowledge as such, but properties of these situations emerge from the complex interplay of retroactions that show up in the situations with which the student interacts. These retroactions must be at the same time sufficiently transparent but also sufficiently "rich" for the student if conditions in which the students learn mathematics are to be created.

This chapter is an attempt to show that we should be less interested in creation as such than about pedagogical and didactical conditions (belonging to mathematics) of its emergence. One of the fundamental paradoxical dimensions of creation that we will try to elaborate is that what students have to learn is precisely what the teacher cannot teach them, and so it therefore corresponds to what students have to "create." In fact, mathematics that already has been discovered is "dead" mathematics, and it is brought to life through its use by researchers[3] but also by teachers as the crucial teacher's role is based on creating the conditions where students may learn mathematics by applying their knowledge in new contexts. With these ends in mind, teachers create situations that show their students the use and interesting aspects of mathematics that they have been taught; but the teachers cannot place themselves in their students' position in order to teach them (Similarly, one cannot walk or speak or sleep for a one-year-old toddler even though, of course, one does his/her best to help the child to learn.). This is what mathematics educators call the didactical contract (Brousseau, 1997; Novotná & Hošpesová, 2009; Sarrazy, 1995). In other words, to teach mathematics is to create conditions for re-emergence of mathematics. Creation of these conditions forms the core of the teacher's work (Bureš & Hrabáková, 2008).

The aim of this chapter is to deconstruct the mystic dimension of this creation in order to grant the teaching of mathematics and the learning of mathematics in their places in both areas: didactical and pedagogical. Didactical suggests learning ready-made mathematics, and pedagogical implies maintaining the sense of creation by the student as a condition and initiator of appropriation of a mathematical activity.

CREATION AND EDUCATION

Considered here in the domain of mathematics, the process of creation as emergence of something new of an intellectual and aesthetic value is fascinating, and it surprises and impresses us through the disruption that it reveals and fills us with enthusiasm with its aestheticism.

> Mathematics, rightly viewed, possess not only truth, but supreme beauty – a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show. The true spirit of delight, the exaltation, the sense of being more than man, which is the touchstone of the highest excellence, is to be found in mathematics as surely as in poetry. (Russell, 1917, p. 60)

Creation seems to have one divine dimension because it appears as manifestation of reality it reveals and that eludes our immediate comprehension. Let us say that we would like to believe as we like to believe the magic of magicians or the fiction in a movie, but the spectacle is more fascinating than the knowledge of how it happens that spoils the delight. Is there anybody who has never been fascinated by the ingenuity of our own children and also of our students? Everything seems to be happening but something has eluded our comprehension; and this is just the mystery that fascinates us and that we do not try too hard to penetrate if we do not want to break the spell; at best when we speak about it, we refer to gift or talent. Creation (as manifestation of talent) therefore seems to be in opposition to education and more specifically to teaching. This conception of creation denies education. But the fact is, as we will demonstrate in this chapter, that there is no creation without education.

CREATION AT THE CROSSROADS OF PARADOXES

Etymologically, creation is a process consisting of "extracting something from emptiness," giving rise to a being or a thing *ex nihilo*. For a long time this concept was attached purely to the religious domain: the God as the creator of the world, seven days of creation, etc. It was as late as the end of the 18th Century that the word started to be used also for "the assemblage of beings and created things"; in other words, something that can be produced even by human activity. However, the idea of uniqueness is still attached to this concept. On the one hand, there is the uniqueness of what is produced (creation as an object) but also the uniqueness of the creator. It is very common in the history of humankind that creations are called by the names of their creators: Pythagoras' Theorem, Fermat's Last Theorem, the Poincaré Conjecture, Einstein's Theory of Relativity, and Bolzano's Paradoxes of the Infinite.

But we are facing a problem here: how can we tell what an original is, first, unique product? This can only be said in reference to the collective, already existing productions. Therefore, there is no creation without a community as community recognises its value in production and decides whether something is worth keeping and valuable for the life of the humankind in practical, aesthetic, scientific, and technological utility. This is one of first paradoxes brought about by creation: Uniqueness and uncommonness of creation cannot exist without the group that recognises these qualities; creativity, which is undoubtedly individual, is basically a collective phenomenon. Without a community, there is no creator.

The second paradox is an immediate consequence of the first paradox: how to recognise what is new? Paraphrasing Menon's dialogue we could say: If we recognise some production as something new, we must have some prior knowledge of it because otherwise we would not have been able to recognise it at all. If we have no prior knowledge, we cannot recognise it as such. The histories of sciences, arts, literature, and other disciplines have witnessed a considerable number of works that were acknowledged years, even centuries, after their production. For example, the numerous works of Bolzano (1781–1848) were recognised as late as 1920.

Education is at the heart of overcoming this paradox of what we are dealing with. The fact is there is no creation without collective memory of production. And education is nothing but the transmission of works. Therefore, there is no creation without education. This is the second paradox: There cannot be creation without transmission of what has already been produced, and at the same time creation cannot be the product of transmission because the only thing that can be transmitted is that which exists.

Here we identify a phenomenon that teachers are more than familiar with: New knowledge can only be born in relation to the former knowledge (which it often destroys). This is undoubtedly a source of inequality; creation can only be born from plenitude and not from ignorance or naivety that is sometimes claimed in connection with young children.

The third paradox is a direct consequence of the second one. If a society, a group, or a family can transmit only what already exists, then each creation requires a transgression because it means to make the non-existent exist and to make the hidden visible. But psychoanalysis shows that the hidden has always kept its relationships with *savoir* and desire; the subject cannot desire what he/she does not have, what is concealed from him/her. Here is one of the prime movers of creation as looking for *savoir*: a *savoir* to see. Consequently, what is hidden is always burdened by prohibitions as with the forbidden fruit of the tree of knowledge in the Garden of Eden from the Bible's Book of Genesis or children's particular attraction to the forbidden or the hidden. Freud (1962) calls this space "the scopic drive" where the "desire to see" is born. Thus creation is always transgression, transgression from the rules in order to see differently, transgression from the hidden in order to penetrate what is masked. But transgression – and therefore creation – cannot be the product of an explicit command or docile execution of the order to disobey. Thomas Kuhn (1962) speaks in this respect of "scientific revolutions," "revolution" in the sense of considering the things in a different way from a different point of view as in the case of Andrew Whiles who studied Fermat's Last Theorem from Galois' and Taniyama-Shimura's works (Singh, 2002). This is the third paradox: To create is to let oneself be, to make the decision to become an author and to accept the position of "the person who founds and constructs." In Latin *auctor* referred to the God, a God creator. Referring supposes that the subject is autonomous and free but as we have already suggested, freedom is possible only in the framework of a culture that is necessarily collective.

This third paradox has its philosophic expression in Kant's (1991) famous formula characterizing the Enlightenment spirit to: "Argue as much as you will, and about what you will, but obey!" (p. 50). An ice-hockey player, a painter, a musician, and a mathematician are free to choose how they play but cannot define the game in which they take part. The freedom of players is possible only if they play by the rules that define the conditions of the possible and play inside the respective communities hockey players, painters, musicians, and mathematicians. The space of creation lies in the space in between the individual freedom and the collective restrictions on how to play, between the structural dimension of the game and the way of playing it. But let us state again that creation is far from restricted only to novelty. It must be of interest and of value to the institution or the community in which it appears. So the creation is always an encounter between a culture at a given moment and the singular desire of a subject nourished by this culture.

The phenomenon is typical for teaching and learning as teachers do (often silently) the sorting out of what must be remembered and what can be forgotten. This dimension of creation is therefore valuable for the teacher. The dimension of marginal novelty and of possible discovery of what Giroux (2008) calls *atypical conducts* are characterised by: marginal character, non-adapted to restrictions, and specific to the stakes of the mathematical situation. For that matter, that is why atypical conducts are relevant for the area of didactics. They cannot be mistaken for "inefficient or deviant conduct" or for "behaviour that has not been adjusted to the assigned problem." As Giroux explains, atypical conducts "confirm the role of the antagonist dimension of the milieu (situation)" and "are thus consequences of appropriation of the real stake of the situation." For instance, mathematical creation requires a game, like the space of limited freedom that is parallel to the role of hinges; if the hinges are too tight it is impossible to open the door, too loose, the door cannot be closed.

To summarise, we can say that creation is an anthropological phenomenon, closely linked to education. Creation enables birth of novelty that is at the given moment considered as useful for the culture and which will be recognised as such by an institution furnished with a collective memory. It is located on the crossroads of the following three paradoxes:

- Paradox of the collective subject that poses the question of relationships between the individual and the society;
- Memory paradox that characterises the dialectics of the ancient or of the "already known" and the new;
- Paradox of authority: to create the means to let oneself discover something that does not yet exist; this permission puts in dialectical tension docility and transgression. Without rules and norms creation is not possible: a human, like a student, is at the same time autonomous and heteronomous. Freedom is possible only through voluntary acceptance of a set of restrictions that define the space of its creation.

These three paradoxes of creation are also in the background of any educational activity and, as we will see, they show more clearly in mathematics education. Let us start by considering the following extract from an episode from a mathematical lesson with 9-year-old students.

> Elodie tells her teacher that some pages in her dictionary are missing: "Look, it jumps from page 122 to page 211!" The teacher takes the opportunity to ask: "How many pages are missing in Elodie's dictionary?" "Easy!" some students

> say. Some students tap on their calculators … then many of them suggest “89,” to which the teacher says: “No!” says the teacher. Refusing to validate these new answers, the teacher says: “You must not only find the right result but also prove that it is correct!” Thirty minutes pass, students offer many results but none of them is valid. Suddenly, Lou announces proudly: “Here it is! I found it, and I can prove it!” Lou comes to the blackboard with her dictionary and says: “I counted it!” Her dictionary is open on page 123 and she starts counting every page, turning the pages one by one. The others protest: “This is cheating!” The teacher’s reaction is: “I forbade no method. All methods are allowed when it comes to *savoir*!”

It is true that Lou did not invent counting as Antonín Dvořák did not invent the notes with which he composed his requiem. What Lou created is the use of counting here and now in order to establish with certainty the solution to the posed problem. The solution itself was not included in the knowledge of counting. It is largely due to the character of novelty of her procedure that makes other students treat her as a “cheater.”

MATHEMATICAL EDUCATION – CREATION OR REPRODUCTION?

To teach is to pass down to the younger generations what the previous generations have produced with the aim to prepare children for the society in which they will live their lives. Because children are unfinished, dependent, and ignorant, they have to be educated. The educator, albeit the parent or the teacher or anybody else, shows examples, explains, justifies, forbids, and says what can be done and what cannot be done, but will never succeed unless the child joins in the educational project.

In fact, what the teacher expects is neither mere docility nor respect to what was said, but the teacher does not expect mere imitation of what was said or done nor mere memorisation of the rules that have been taught. The teacher expects special use of what has been taught in new situations that the students have not yet met. It is exactly in this respect that learning may be considered as a sort of what Baker and Hacker (1986) call normative creation, creation because the subject explores new spaces, solves new problems; also normative because the way it is done *must* conform to the rules that define the space of his/her action. Similarly, a football player may create his way of playing but within the framework of the given rules of the game that—at the same time—restrict his activity as well as define his freedom. The difference between a good and a bad student is not in their knowledge of algorithms but in the way they use them. After all, the teachers are not wrong when they say to a student: “You know the lesson but you have not understood a thing!” Learning, of course, is storing in memory but comes to surface mainly in the form of students’ own production in the limits given by the rules as they have been taught.

The idea of the child as creator developed rather late. However, it was definitely here in the 18th Century with the Lumières and their concept of social contract. For many years it was one of the fundamentals of active pedagogy. Let us recollect at this point what J.J. Rousseau wrote in *Emile*:

> Let him know nothing because you have told him, but because he has learnt it for himself. Let him not be taught science, let him invent it. If ever you substitute in his mind authority for reason, he will cease to reason; he will be a mere plaything of other people's opinion. (Rousseau, 1991, p. 564)

One could assume that Rousseau had anticipated even the essence of didactics that developed in the end of 1960s with the theory of didactical situations (Brousseau, 1997). This theory outlines a method that enables the student to understand and "discover science" independently, on his/her own:

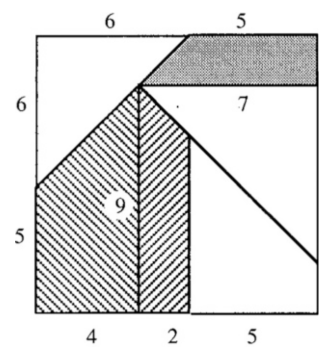
> Keep the child dependent only on things. […] Never offer to his indiscrete will anything but physical obstacles or punishments that arise from the actions themselves, […] Experience or lack of strength alone ought take the place of law for him. (Rousseau, 1991, p. 238)

This method is correct as learning enables us to change the students' points of view. Although we can teach this change, we cannot force it upon the students. It is similar to suffering; everybody knows what suffering is, but suffering is an individual experience and does not come to surface even though others might feel and sense that another person is suffering. Moreover it is not possible for anybody to suffer in place of the other; one can try to help, try to soothe, but one cannot suffer in another's place.

The idea of the child creator is often replaced by new pedagogies that tend to be rooted in the romantic movement reinforced by Piaget's constructivism. Piaget claims that everything that one teaches a child prevents the child from inventing it (Piaget in Bringuier, 1980). Piaget was right; children show extraordinary plasticity in their behaviour. Children seem always ready for challenges, come up with new problems, and think up new forms of adaptation to situations. Moreover, children never cease creating more and more complex problems. But what Piaget did not explain—as it was not in his project—are the conditions in which students can meet problems that allow them to learn exact mathematical knowledge. If these conditions are ignored, creation is isolated from its educational and cultural dimensions. We end up with the previously mentioned ideology of talent. The theory of didactical situations developed in response to this blind spot in Piagetian theory. What properties must situations have if they are to enable students to learn what cannot be taught directly? What constitutes the core of mathematical activity where learners search, make conjectures, confront convictions, justify, insist, persuade, prove, and *do* mathematics?

Example of a Situation

This is a situation of the study of linear applications: Enlargement of a puzzle (extracted from Guy Brousseau (1997, p. 177).



Instructions: Here are some puzzles. You are going to make some similar ones, larger than the models, according to the following rule: the segment that measures 4 cm on the model will measure 7 cm on your reproduction. I shall give a puzzle to each group of four or five students, but every student will do at least one piece or a group of two will do two. When you have finished, you must be able to reconstruct figures that are exactly the same as the model.
Development: After a brief planning phase in each group, the students separate. The teacher has put an enlarged representation of the complete puzzle on the chalkboard. Almost all students think that the thing to do is to add 3 cm to every dimension. […] The result, obviously, I that the pieces are not compatible.

This situation clearly shows that students can learn by interacting with the situation; the situation enables (among other things) students to invalidate the classical model of addition: If $4 \rightarrow 7$ $(4 + 3)$, then $5 \rightarrow 8$ $(5 + 3)$.

On the condition that each student gets one puzzle with the goal of illustrating the use of proportionality, will all students learn the same? Definitely yes. The students will have learned the same functions and same mathematics, but in this situation they will learn something extra—a way of doing mathematics. Let us recollect at this point, for example, that thanks to various manipulations by cutting and comparing that Galileo managed to work out the formula for calculation (approximate) of the surface of a cycloid.

This example demonstrates that if a teacher teaches a rule, the student learns *simultaneously a way of doing mathematics* without being explicitly taught the rule—very similarly to the "practical sense" in the sense of Bourdieu (1984). This way of doing mathematics contributes to mathematical education in that it determines, not mechanically, the use of teaching rules. It is obvious that we must study the conditions of the students' mathematical activity. The tension between the two aspects—the rule and its use—is often the centre of attention to those looking for improvement of teaching and learning mathematics. The relationship between the mathematical rule and its use is generally approached from one or the other of the following opposing poles.

- Sometimes the stress is put on teaching the concepts and on exercises and problems designed to reinvest and drill knowledge already taught.
- Sometimes the focus is on mathematical culture, on the possibilities of a student's creation, and on the construction of knowledge.

This opposition is misleading because even though it marks one of the borders between "active" and "classical" pedagogy, it makes the teacher ask many questions. Should teachers make their students' "heads quite full" or "heads well done" in Montaigne's words? We should hope for both. This is one of the contemporary impasses of teaching and learning mathematics. One of the possible reasons for this impasse is the fact that this debate is counterproductive. Because knowledge of algorithms does not mean better knowledge of arithmetic, just as knowledge of the rules of chess allows us to "play chess" but does not prevent us from making mistakes when playing or losing the game. The idea is simple but not trivial.

CONTRIBUTION TO THE STUDY OF CONDITIONS OF CREATION: RESPONSIVENESS TO DIDACTICAL CONTRACT

Methodology

Asked to solve a set of arithmetical problems in four different situations (see below), 155 students aged 9 were presented the following problem that we call "pseudo-multiplicative":

> A snail is at the bottom of a well. He decides to leave the well. We know that it will take him 6 days to get out of the well. How long will it take three snails to get out of the well following the same path?

This type of problem brings a less ordinary use of multiplication because it requires the student to: (1) use multiplication knowledge to demonstrate that his/her solving process cannot make use of this operation and (2) produce an answer without calculating (less usual use in school).

All four situations are situations of evaluation, yet they differed from each other in their level of authority. For instance, depending on the situation, the person posing the problems might have been another student, the teacher, or the researcher. Each situation also differed in the individual or collective stakes connected to verification.

- Situation 1: The researcher asks the students to solve a series of problems (among which the target problems are included). The students are informed that the test will not be marked.
- Situation 2: This test is presented to the students as a competition between classes, in which each class chooses which of the posed problems will be assigned to the other classes. The test is divided into two phases: 1) the presentation of the rules of the "competition"; each student poses a problem and solves it and consequently submits it to the researcher; 2) the test itself: the researcher poses

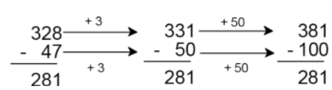
his/her own problems. Here, the nature of the activity is not individual as in the other situations but collective.
- Situation 3: Each teacher carries out evaluation that he or she would normally carry out in the end of the term. This evaluation includes the target problem. Here, the nature of the activity is clear to the students: the activity is individual and marked by their teacher.
- Situation 4 ("warning situation"): The aim of this situation is to verify whether the students are able to correct a "defective" problem assignment. That is why the students were informed of the presence of both non-calculable and calculable (classical) problems in the given set of problems.

The results clearly show that the decisions concerning the target problem (absence of an answer, answer calculated "3 x 6," or the correct answer "6 days") can be accounted for by the type of the situation rather than by the students' school level. When the investment is collective and the degree of authority is less developed, the students take the freedom to produce an answer without calculating. What we now have to explain are the differences in student solutions manifested within the same situation.

Didactical Environment and Responsiveness to Didactical Contract

The responsiveness to didactical contract is a concept that we designed for labeling the students' decisions in relation to the situations where they had to make non-ordinary decisions and let themselves do something that they were not used to doing. The following is an example of responsiveness to didactical contract:

> A few days before this episode, the teacher taught his 9-year-old students the following algorithm for calculating the difference between two numbers.



In the evaluation prepared by the teacher, the researcher included the following exercise: How would you carry out the following calculations?

a. 875 - 379 = ______________________________
b. 964 - 853 = ______________________________
c. 999 - 111 = ______________________________

Sixteen out of 19 students applied the algorithm taught by their teacher in all three exercises including the following third one.

999 -111 = 1008 - 120 = 1088 - 200 = 888.

It can be presumed that students ask themselves what the teacher expects of them. Should they show that they master the taught algorithm or should they use the classical procedure (that would be much simpler) for answering the question c? It is this implicit attitude that we call "responsiveness to didactical contract."

Of course we do not intend here to measure the students' creative abilities; we want to contribute to evaluation of the flexibility of their knowledge according to the situations that form the major components of the creativity—their ability to let themselves do something non-ordinary.

Analysis of Effects of Didactical Environments on Creativity

We studied the effects of two strongly contrasted models of teaching on the phenomena of responsiveness to didactical contract. The following were some observations:

- The Magisterial Model bases work on repetition, and the basic teaching scheme could be described "show-retain-apply." The teacher hopes that students will be able to generalise and will apply the piece of knowledge elsewhere. Teaching strives to hand over procedures and algorithms necessary for solving problem-types that are often rooted in social life. Typical for such teaching are weak openings and low varieties of situations. During lessons, teachers quickly teach a solving model and then assign their students increasingly more complex exercises that are consequently checked collectively on the blackboard. These classes are weakly interactive.
- The Activating Model corresponds to what could be called "active pedagogy" and often refers to Piagetian constructivism. The problem is considered as the privileged tool for "making sense" to knowledge. Teaching is characterised by strong variability in the organisation and management of situations. Teaching regularly uses group work. Assigned problems are in most cases complex and open. These classes are strongly interactive.

Let us now turn our attention to the effects of the culture of classes on the phenomena of creation: How can these ways of teaching influence students' approach and attitude to "novelty"? Do they or do they not allow a non-ordinary solution?

Results and Comments

In case of the "snail" problem, it was observed that 48% of students from the "activating" model produced answers without calculating. In contrast, 17% of students from the "magisterial" model produced answers without calculating [χ^2 = 6.08; p. <.04]. These differences are valid for the same school level independent of the situation of their production. These models show to be suitable for explanation of the phenomena of responsiveness to didactical contract. In other words, the more chance the students have to confront the rules with weakly repetitive situations, which is the case in the activating model, the more they let themselves use them in new situations. Reciprocally, the more repetitive the teaching is, which is the case of the magisterial model, the less the students let themselves deviate from the use of rules.

Can we assume that one model of teaching should be given priority over the other one? This would definitely be wrong. If we assign the same students problems of high difficulty in weakly decontextualised situations with the same or very similar context to the one previously described, results concerning the influence of teaching styles may be radically different.

Conditions of the Experiment

The problems used for the experiment correspond to the fourth additive structure of Vergnaud's typology (1982). This structure is specific as it uses only positive and negative transformations (win or lose) without any indication of the initial numerical state. An example of this type of problems follows:

> Dominika plays two rounds of marbles. She plays one round. In the second round she loses 4 marbles. After the two rounds she has won 6 marbles. What happened in the first round?

The experimental plan is classical: 22 problems of various difficulty were assigned to students in a pre-test. This was followed by 2 lessons in the interval of one week from one lesson to another; in the end the same problems were assigned to students again. An 'index of progression' (I_p) was defined for each student.

Results and Comments

When evaluating the effects of the teaching, two aspects were considered.

- The first consideration is called *efficacy* and corresponds to the measure of effective performances recorded in the post-test when controlling variables likely to have influences the observed results (the students' school level).
- The second consideration is called *equity* and measures differential efficacy for a given group of students, taking into account their initial level (the pre-test results).

The magisterial model looks to be more fair with students making significantly more progress than students from the activating model ($f_1 = 3{,}73$; p. $< .05$) and also more efficient since student performances are significantly better ($f_1 = 5{,}10$; p. $< .01$). These effects are evident in particular for weak students (efficacy: $f = 20{,}26$; p. $< .01$ – equity: $f = 20{,}26$; $p < .01$).

Should these last results make us re-evaluate our previous conclusion, and do results confirm that the magisterial model is more beneficial than the activating one this time? On the one hand, all research is only a window opened to the universe of practices whose temporalities are not analogous. Nothing here allows us to conclude that if the number of lessons was greater – in our research we were limited to two lessons on the involved teachers' request – the performances would necessarily be the same. The speed of learning is probably slower in the activating model, but the time provided for the teacher also has very significant effects on structuration and management of didactical organisation (Chopin, 2011).

CONCLUSION

The results lead to the fundamental questions about how and where to direct education. Should the goal of education to be the "head quite full" or the "head well done"? Should we look for good teaching of algorithms or should we allow students to be creative and use these algorithms in new situations? This makes us ask what kind of women and men the school should produce. Obviously, if the magisterial and activating models always appear hand in hand, they are in a paradoxical relationship. Here we again come across the paradoxes of creation discussed in the first part of the text.

The theory of didactical situation was born from theorisation and scientific study of the conditions that allow us to overcome this paradox; if its recognition in the scientific community is undoubtable[4], its dissemination and use in teacher training remains strongly limited, which Marchive (2008) points out in his recent study. Is this something to be regretted? Definitely yes, because teacher training seems to be an efficient tool that will enable teachers to avoid this impasse. It is crucial that teachers believe in student creativity, but this pedagogical belief leaves teachers often insufficiently prepared if they are to construct conditions for mathematical creation. Pedagogical willingness as such or humanist spirit are powerless tools when teachers come face to face with students' ignorance and lack of comprehension.

It would be desirable to develop significantly teachers' didactical culture, but it would be wrong to think that it could replace pedagogical knowledge. It would be a serious mistake because teachers as well as students need both certainty and illusion.

If an educator contributes to clarification of the conditions under which creation of *savoirs* new to the student is possible (that do not depend on the student but on the mathematical culture itself), it is the pedagogue and nobody else who is responsible for preparation of socio-affective conditions that will enable his/her students to take part in an activity. This activity must be an adventure for students that only they can experience and that nobody else can do it in their place—the adventure of grasping the whole world in one day and in turn engaging themselves in the adventure of mastering the subject matter. How can one imagine that they would be able to produce the new unless they have had the chance to experience it actively? This is our noble mission: to create conditions enabling this mathematical creativity.

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NOTES

[1] Translation into English: J. Novotná. French original: « Il est indispensable que tout enseignant, chaque jour, commence sa classe comme si les connaissances qu'il propose à ses élèves étaient découvertes pour la première fois au monde et comme si cette rencontre était décisive pour... l'avenir de l'humanité.»

[2] In the chapter two types of knowledge are distinguished: connaissances and savoirs. Briefly we can say that "isolated parts are acquired as *savoirs* connected by *connaissances*" (Brousseau, Sarrazy, 2002). For a detailed description, see e.g. (Brousseau, 1997).

[3] Example: Taniyama-Shimura's conjectures came back to "life" in connection with the success of Andrew Wiles with the last Fermat's theorem.

[4] G. Brousseau was the first who was awarded Felix Klein's medal from ICMI in July 2004 at ICME congress in Copenhagen.

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ESTHER LEVENSON

INVESTIGATING MATHEMATICAL CREATIVITY IN ELEMENTARY SCHOOL THROUGH THE LENS OF COMPLEXITY THEORY

This chapter explores the practical application of complexity theory to the investigation of mathematical creativity in elementary school classrooms. While previous studies have investigated ways of assessing students' potential for mathematical creativity (Lee, Hwang, & Seo, 2003; Mann, 2009) and specific ways of promoting mathematical creativity (e.g. Levav-Waynberg & Leiken, 2012), this study investigates mathematical creativity as it emerges in classrooms as part of the regular lesson. Three classrooms were observed where the teachers were not explicitly implementing a program aimed at promoting creativity. Yet, when the lessons were reviewed, it became apparent that they included episodes where manifestations of mathematical creativity were evident.

Analysing exactly which of the classroom participants were being creative, who was responsible for what, and what led to the creative endeavor in these classrooms proved difficult. In a previous article (Levenson, 2011), I employed theories related to collective creativity (e.g. Hargadon & Bechky, 2006; Paulus, Larey, & Dzindolet, 2000) and theories related to collective mathematical understanding (Martin, Towers, & Pirie; 2006) to investigate notions such as collective fluency and collective flexibility in the classroom. In this chapter, I look at the same data using the lens of complexity theory.

Looking at the same situation from different perspectives is not new (e.g. Even & Schwarz, 2003) and can afford the researcher a richer and more detailed view of the data (Bikner-Ahsbahs & Prediger, 2006). In this case, complexity theory takes into account the dynamic interaction and interdependence of classroom participants focusing on and making sense of how knowledge, and in this case creative thinking, emerges at the group level. In addition, as Hurford (2010) claimed, "it may well be that the most important affordance of systems-theoretical approaches to learning is in the language of complexity itself, because the language helps all stakeholders to fabricate their own internal models of dynamical learning systems" (p. 583). This chapter is the result of applying this approach, along with its attending language, to investigating the emergence of mathematical creativity in elementary school classrooms.

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 35–51.

MATHEMATICAL CREATIVITY IN THE CLASSROOM

As the focus of this chapter is on creativity among young students, it is not concerned with the creativity of a few eminent persons who have made a significant and lasting contribution to society (sometimes known as *Big-C* creativity). Instead, this study is concerned with everyday creativity (*little-c* creativity) as it is manifested in the classroom. It focuses on students' "novel and personally meaningful interpretation of experiences, actions, and events" (Kaufman & Beghetto, 2009, p. 3). This view is in line with Runco's (1996) view of creativity as "manifested in the intentions and motivation to transform the objective world into original interpretations, coupled with the ability to decide when this is useful and when it is not" (p. 4).

Focusing on mathematical creativity, Liljedahl and Sriraman (2006) differentiated between professional and school-level mathematical creativity. Professional mathematical creativity relates to work that significantly extends the body of knowledge and opens up new directions for other mathematicians. School-level mathematical creativity includes unusual and/or insightful solutions to a given problem or viewing an old problem from a new angle, raising new questions and possibilities. This study adopts the view that mathematical creativity is "an orientation or disposition toward mathematical activity that can be fostered broadly in the general school population" (Silver, 1997, p. 75). As such, the product of mathematical creativity in the classroom may be original ideas that are personally meaningful to the students and appropriate for the mathematical activity being considered.

One of the hallmarks of creativity in general and mathematical creativity specifically is divergent thinking. Divergent thinking is often measured in terms of the fluency, flexibility, and originality of ideas produced. Silver (1997) related fluency to "the number of ideas generated in response to a prompt" (p. 76). Flexibility, according to Silver (1997) refers to "apparent shifts in approaches taken when generating responses to a prompt" (p. 76). Leikin (2009) evaluated flexibility by assessing if different solutions employ strategies based on different representations (e.g., algebraic and graphical representations), properties, or branches of mathematics. Flexibility may also be thought of as the opposite of fixation. In problem solving, fixation is related to mental rigidity (Haylock, 1997). Overcoming fixation and breaking away from stereotypes are signs of flexible thinking. Haylock further differentiated between content-universe fixation and algorithmic fixation. Overcoming the first type of fixation requires the thinker to consider a wider set of possibilities than at first is obvious and to extend the range of elements appropriate for application. The second type of fixation relates to when an individual adheres to an initially successful algorithm even when it is no longer appropriate.

Novelty and originality are also related to mathematical creativity. According to the systems model of creativity, when an individual employs the rules and practices of a domain to produce a novel variation within the domain content, then that individual is being creative (Sriraman, 2008). In the classroom, this aspect of creativity may manifest itself when a student examines many solutions to a problem, methods or answers, and then generates another that is different (Silver, 1997). In this case, a novel solution infers novelty to the student or to the classroom participants. Originality may also be measured by the level of insight or conventionality with respect to the learning history of the students (Leiken, 2009). The terms originality and novelty may seem synonymous; and indeed, some researchers have used them interchangeably. However, each of these terms stresses different elements. Novel may refer to "new" while original may refer to "one of a kind" or "different from the norm." While it seems likely that a "one of a kind" idea will also be "new" and vice versa, it is sometimes the case that an idea, especially one raised in the classroom, may be new to a student; but if other students have the same idea, it may not be original.

One of our goals as mathematics educators is to promote mathematical creativity among our students. Toward this end, several studies have focused on the teacher and pedagogical aspects of teaching for creativity (Bolden, Harries, & Newton, 2010; Jeffrey & Craft, 2004; Sawyer, 2004) while other studies have focused on the types of tasks that can promote mathematical creativity (Kwon, Park, & Park, 2006; Silver, 1997). However, creativity is not always something that can be planned for or predicted. More likely, it can be occasioned. Especially in the classroom, where students interact with each other, the teacher, the content, and the environment, it may be said that the creativity that emerges is the result of different agents coming together to complement each other thus opening up possibilities that might not have existed or been acted upon at the individual level. Put simply, viewing the classroom as a complex system affords us the possibility of examining how creativity may emerge. The next section briefly reviews theories related to complex systems and how they relate to education.

THE CLASSROOM AS A COMPLEX ADAPTIVE SYSTEM

The classroom may be referred to as a Complex Adaptive System "in which many players are all adapting to each other and where the emerging future is very hard to predict" (Axelrod & Cohen, 1999, p. xi). This is in contrast to a simple system, which has a limited number of components, few interactions, and is decomposable (Casti, 1994). If the connections between the components are severed in a simple system, the system will more or less function as it did before. The classroom may be viewed as a complex system because the components of the system—the teacher and the individual students—may have different goals and driving forces, yet each individual is highly connected with the other; the decisions and actions of one may affect the decisions and actions of others (Hurford, 2010). In addition, the knowledge and insights that are shared and creativity that emerges can hardly be predicted at the onset of the lesson.

Emergence is a central theme of complexity theory. It implies that "given a significant degree of complexity in a particular environment, or *critical mass*, new properties and behaviours emerge that are not contained in the essence of the constituent elements, or able to be predicted from a knowledge of initial conditions" (Mason, 2008, p. 2). In other words, a slight change in initial conditions, or a slight change in the behaviour of one agent, may shift the direction of the larger system. The system maintains itself by adapting to new situations and learning from emergent interactions.

Davis and Simmt (2003), in their review of the parallels between complexity science and theories of knowing, suggest five features or conditions that must be met in order for systems to arise and maintain their ability to adapt and learn: (1) internal diversity, (2) redundancy, (3) decentralised control, (4) organised randomness, and (5) neighbour interactions. Internal diversity refers to the different ways members of the community contribute to finding solutions to a given problem. In a sense, it represents the possible responses to emergent circumstances and thus its quality ensures the survival of the system. On the other hand, if members of the system are to communicate, they must share some similarities such as background, language, and purpose. Redundancy refers to the similarities that enable the system to cope with stress and allow for different members to compensate for others' failings. The complements of internal diversity and redundancy are also related to studies that have investigated group creativity. For example, a situation where diverse individuals come together to solve a problem (such as in the work place) may begin with divergent thinking, but eventually, ideas must converge in order to solve the problem at hand. On the one hand, the different backgrounds and knowledge bases of a diverse group may contribute different perspectives for consideration. On the other hand, diversity may be so wide as to hinder individuals as they strive to understand different ideas and come up with an agreed-upon solution (Kurtzberg & Amabile, 2001).

When viewing the classroom as a system, decentralised control means allowing students to share in the decisions about what is and what is not acceptable. Organised randomness refers to a "structural condition that helps to determine the balance between redundancy and diversity among agents" (Davis & Simmt, 2003, p. 154). In a complex system there are boundaries and constraints, but the possibilities within these boundaries are rich and numerous. In the mathematics classroom this could mean providing enough of a framework so that students can focus on a certain problem while simultaneously allowing sufficient freedom for students to offer various and flexible responses. The last condition, neighbour interactions, refers to mathematical ideas or insights that interact with each other. In the following sections, I illustrate how mathematical creativity can be seen to emerge by viewing the classroom as a complex system.

CLASSROOM EPISODES

Setting

In this section, three episodes are reviewed. Each episode depicts segments of a mathematics classroom where the teacher was observed teaching a "regular" lesson. That is, the lessons were not planned specifically for observation nor did they have specific aims other than to review or teach what was considered part of the scheduled content sequence. The teachers taught according to the mandatory mathematics curriculum using state approved textbooks. They taught in local public schools located in the same middle-income suburb of Tel Aviv, a major city in Israel. During the school year, each class was observed approximately ten times. During classroom observations, the focus was on students' interactions with materials, other students, and teachers and the ways in which "ideas are picked up, worked with, and developed by the group" (Martin, Towers, & Pirie, 2006, p. 152). All lessons were video recorded and transcribed by the researcher who also took field notes during the observations. For each episode, some preliminary background of the classroom is offered, followed by a transcription with minimal comments. After the transcription, elements of mathematical creativity evident in the transcription are reviewed. The emergence of this creativity is then analysed through the lens of complexity theory by referring to some of the features of complex systems such as internal diversity and redundancy.

Episode 1: Internal Diversity, Redundancy, and Occasioning Mathematical Creativity

This episode was taken from a sixth grade class consisting of 28 students, 16 girls and 12 boys. The teacher, Hailey (not her real name), had 14 years experience teaching mathematics in the elementary school system, mostly teaching fifth and sixth grade classes. The lesson depicted below took place in the middle of the school year, where the main topic of the lesson was multiplication of decimal fractions. The class had already been introduced to this topic and had already practiced the procedure for multiplying decimal fractions during previous lessons. Hailey put the following problem on the board: __ × __ = 0.18, and asked the class, "What could the missing numbers possibly be?" Many children raised their hands and the teacher commented, "There are many possibilities." She then called on one at a time:

Gil: 0.9 times 0.2.
Teacher: Another way. There are many ways.
Lolly: 0.6 times 0.3.
Teacher: More.
Tammy: 0.90 times 0.20.
Teacher: Would you agree with me that 0.2 and 0.9 is the same [as 0.90 and 0.20]? I want different.
Miri: I'm not sure. 9 times 0.02.
Teacher: Nice. Can someone explain what she did?
(The teacher and students then review the rules for multiplying decimal fractions.)

At this point, note that although Gil and Lolly gave different answers both may be considered similar in that they consisted of two numbers with one digit after the decimal point. Tammy broke the mould by using numbers with two digits after the decimal point. From a mathematical point of view, as noted by the teacher, Tammy's answer is the same as Gil's. On the other hand, from a student's point of view, 0.9 may be very different from 0.90. In addition, as will be shown later on, different representation of the same number may afford different possibilities and thus representing 0.9 as 0.90 may not only be acceptable but even preferable.

Tom:	What about 0.18 times 0.1?
Tad:	No.
Teacher:	Why not?
Mark:	[The answer would be] 0.018 because there would be three digits after the decimal point.
Teacher:	Ah. Ok. Thank you. We want a number with two digits after the decimal point.
Gad:	0.18 times 1.
Ben:	And 1 times 0.18.
Teacher:	You're using the commutative property of multiplication. But, it's really the same as Gad's answer.
Toby:	18 times 0.1?
Many students:	18 times 0.01.
Teacher:	Let's move to another problem. (The teacher writes on the board the following problem: __ × __ = 0.012.)

Regarding mathematical creativity, the task presented by Hailey may be called a multiple-solution task that invites divergent thinking (Leiken, 2009). All together, the class produced five different correct solutions. Perhaps, if more time was available, the class could have produced more solutions. Regarding flexibility, the second solution, 0.6×0.3 followed more or less the same strategy as the first solution 0.9×0.2. The last three solutions, 9×0.02, 0.18×1, and 18×0.01, differ from the first two solutions but may be considered similar to each other. Each example consists of one factor that is a whole number and a second factor that is a decimal fraction with two digits after the decimal point. In addition, there was one attempt to find a solution that included a factor with one digit after the decimal point and a second factor with two digits after the decimal point.

Viewing the episode through the lens of complexity theory, what stands out is the balance between internal diversity and redundancy that allows the students to not only raise different suggestions but to evaluate each other's suggestions as well. Diversity was specifically promoted by the teacher who encouraged the students to find different solutions. Diversity may also be found in the various solutions, acceptable and unacceptable, that arose during the episode. Diversity may also be seen in the different ways in which students contributed. Some students hesitantly offered solutions implicitly seeking confirmation. Others boldly stated their solution. Still others took the role of evaluators. Yet, the students were also able to compensate for each other's deficiencies. There were three instances where one student put forth an incorrect or unacceptable solution and others, building on the idea, corrected the situation. When the teacher does not accept Tammy's solution of 0.90 times 0.20, Miri is able to build on Tammy's idea of changing the place of the decimal point and come up with an acceptable solution. When Tom changes both the factors and the place of the decimal point, he comes up with an incorrect solution. Gad, using the same factors, comes up with a correct solution. When Toby suggests the incorrect solution of 18 times 0.01, many students chime in with the correct solution without the teacher intervening. In other words, the dynamic interactions among participants allow the system to right itself.

Another feature of a complex system is decentralised control. In this episode, although the teacher introduced the task, she invited the students to "agree" with her that 0.9 times 0.2 is the same solution as 0.90 times 0.20. More poignantly, we see the students beginning to evaluate each other's solutions while the teacher merely asks them to explain their disagreement. Organised randomness was produced in one sense from the task itself bound by the need to find factors that multiply to 0.18 and yet with many possible solutions. To this, the teacher added additional bounds, pointing out that 0.2 and 0.20 are essentially the same and that using the commutative property of multiplication does not lead to different solutions. As opposed to the teacher's invitation to the students to agree with her that 0.9 is the same as 0.90, in the case of the commutative property, she declares the status of this solution without attempting to view the solution from the student's point of view. In other words, the teacher set certain constraints but still left room for variation. Finally, when considering neighbour interactions, two major ideas may be considered "neighbours" in that they are tossed around and interact with each other producing a variety of solutions: the number of digits after the decimal point and the factors of eighteen. To summarise, the collective fluency and collective flexibility exhibited in these episodes (Levenson, 2011) can be seen to emerge from the classroom behaving as a complex system.

Episode 2a: Balancing Stability and Change in a Fifth Grade Classroom

This episode took place in a fifth grade classroom taught by Nina (not her real name). Nina had eight years experience teaching fifth and sixth grades. There were 28 students in the class, 12 girls and 16 boys. The students had previously been introduced to decimal fractions, had learned to convert back and forth between decimal fractions and simple fractions, and they had recently learned to add and subtract decimal fractions. The main topic of the current lesson was reviewing addition and subtraction of decimal fractions. The following problem, taken from the classroom textbook, was given as a homework assignment by the teacher and was reviewed in class at the request of one of the students.

Complete the following sequence:

$$\frac{5}{100}, \frac{30}{100}, \frac{\_\_\_}{100}, \frac{\_\_\_}{100}, \frac{\_\_\_}{100}$$

The following discussion ensues:

Teacher: After 30/100, mmm hundredths, and again, mmm hundredths, and again. They want a sequence. What is a sequence?
Uri: It continues with jumps.
Teacher: Equal jumps. The jumps must be equal. What types of jumps are there?
(A few students say out loud different numbers: 25 and 25/100.)

Teacher: That's the size of the jump. You mean to add 25/100.
Uri: Can the jumps be in multiplication?
Teacher: Wonderful. That's exactly what I mean. If I jump by adding 25/100 then the next will be 50/100. Now, you mentioned another type of jump. We didn't learn that yet…it's part of next year's syllabus. But, there are also multiplication jumps. Who said that going from 5/100 to 30/100 means that I added 25 [hundredths]? I can also multiply…
Sam: By 6.
Sarah: 180.
Teacher: 180 hundredths.

The first part of this exchange focuses on clarifying what is meant by jumps (they have to be equal), types of jumps (adding or multiplying), and sizes of jumps (25/100). It is worth noting that Uri thought of multiplication jumps despite the fact that multiplication of simple fractions and decimal fractions had not yet been introduced. Furthermore, although it is technically part of next year's curriculum, the teacher does not dismiss this idea. Finally, two more children contribute to the idea by carrying out the actual multiplication.

Uri: That's what I did at first. But I thought it was a mistake.
Teacher: Is that allowed?
Tina: I thought that it would be a mistake.
Nat: But then you get big numbers.
Teacher: So, you can use a calculator.
Nat: Then you can also divide.
Teacher: You can divide, but not here (referring to the jump from 5/100 to 30/100).
Nat: You can multiply by 6 and then divide by 3.
Teacher: Ok. That's also a type of sequence. Multiply by 6, divide by 3, and then again multiply by 6 and divide by 3.
Tina: But, that's not good. You need equal numbers.
Teacher: This is a different type, but it is certainly acceptable. Let's try it.
Tina: But, it won't come out. You need equal numbers.
Teacher: Let's just say that when the textbook requests a sequence, they generally don't mean this type. They usually mean jumps that are the same each time. But, this is definitely a sequence.
Tina: But, they are not all equal.
Dan: You can also have more than two types of jumps. Multiply, divide, and add.

This episode displays several instances of mathematical creativity. Most notable are the original ideas of Uri and Nat. Uri suggests using multiplication, despite the fact that this operation has not been introduced to the class in conjunction with fractions. Nat suggests continuing the sequence with unequal jumps, an original idea in light of the teacher's comment that jumps must be equal. Finally, Dan suggests employing three mathematical operations at once in the same sequence. Perhaps, employing multiplication and division may be allowed because they are essentially inverse operations. But to consider addition in the same sequence as multiplication and division is indeed original. In short, the mathematical creativity displayed in this episode by the students is an illustration of what Liljedahl and Sriraman (2006) termed school-level mathematical creativity. It includes unusual solutions to a given problem that essentially show how students can view a familiar problem (such as continuing a sequence) from a new angle, raising new questions and possibilities (such as having unequal jumps).

Regarding flexibility and its counterpart fixation, two students claim that they thought of using multiplication but dismissed the possibility. Nat, who claims that he would end up with "big numbers," shows signs of content fixation. Recall that according to Haylock (1997), overcoming content fixation requires the thinker to consider a wider set of possibilities than at first is obvious and to extend the range of elements appropriate for application. In this case, the content fixation may have been brought on by previous textbook examples that refrained from using "big" numbers. Keeping the door open for additional possibilities, the teacher is quick to negate this excuse. Going from a standard review exercise to exploring the nature of mathematical sequences, the teacher also exhibits flexibility in her willingness to change directions. All together the class came up with four different solutions to the problem.

When viewing this episode through the lens of complexity theory, what first comes to mind is the tension between pursuing stability and change (O'Day, 2002). On the one hand, the teacher begins with the familiar practice of reviewing homework. Knowing that the aim of the homework is to practice adding fractions, the teacher advocates using equal jumps to finish the sequence. So far, we have stability. Using multiplication jumps, Uri introduces a change. This results in another change, the production of big numbers. Uri's reluctance to use multiplication may be attributed to content fixation or to his desire for stability. We thus begin to see a connection between creativity and complexity theory. When the teacher and students are ready to give up stability, they move forward with original ideas. Throughout the episode, Tina is the voice of stability as she repeatedly calls for equal jumps. The teacher attempts to pursue both stability and change by acknowledging that equal jumps may be the norm and possibly what the textbook author implied, but unequal jumps are acceptable. Finally, the system adapts to the original idea of unequal jumps and accepts sequences that employ two and even three different operations.

Referring back to the features of a complex system mentioned by Davis and Simmt (2003), internal diversity can be found in the different roles played by the participants. Some students raise ideas (Uri, Nat, and Dan), some act upon the ideas of others by carrying out the arithmetic (Sam and Sarah), while others raise objections (Tina). Yet the students and teacher were able to interact and build upon each other's ideas. Uri suggests using multiplication jumps. Nat expands upon Uri's idea by suggesting the use of both multiplication and division jumps in the same sequence. It seems like he is responding to the problem of producing big numbers. If we employ division jumps along with multiplication jumps, then the sequence will not increase so rapidly. Dan continued Nat's premise of using unequal jumps and suggests employing three mathematical operations at once in the same sequence. Would Dan have come up with this idea if Nat had not previously suggested using unequal jumps? Would Nat have suggested using unequal jumps if Uri had not brought up the possibility of multiplication jumps? Of course, we cannot answer these questions. However, these questions illustrate the interaction between the participants as well as the interaction among ideas that Davis and Simmt (2003) call neighbour interactions.

Another feature of the complex system is decentralised control. Is there one person at the helm steering the others? While at first it seems that the teacher is setting the rules; she quickly allows the students to change the course of action. She also asks the other students if multiplication jumps are allowed, deferring her judgment until the students have thought about it themselves. Finally, while the activity is bound by the need to continue a mathematical sequence, there is sufficient room for several possibilities to arise. In other words, there is organised randomness. To summarise, the original ideas that emerge in this lesson can be seen to emerge from balancing change with stability and are supported by the classroom acting as a complex system.

Episode 2b: Adapting to the Emergence of Creativity

This episode is a direct continuation of the previous episode. After the above discussion, the teacher goes back to reviewing decimal expansions, addition and subtractions of decimal fractions, and reviews another homework problem involving a sequence. She then presents another sequence from the classroom textbook, but one that was not given for homework.

Teacher: Here's one that's more difficult. Let's look at another problem. Build a sequence that has in it the numbers 0.2 and 1.1.

(Four children raise their hands.)

Dan: Add 0.9.

Teacher: You're saying to place them next to each other and then the difference is 0.9. Then what would be the next number?

Judy: 2.

Teacher: And then?

Mark: 2.9.

Teacher: But you can make a different sequence. Who says that the two numbers

	have to be next to each other? It doesn't say that they have to be one next to the other.
Tali:	You can do jumps of 0.3.
Teacher:	Jumps of 0.3. Let's see. What would come next? (The teacher writes on the board 0.2, 0.5, 0.8, 1.1) Are there more [ways to complete the sequence]?

(The bell rings signalling the end of the period, but the teacher continues.)

Teacher:	Sit a minute. One more second.
Dan:	You can put the sequence in backwards order and do subtraction.
Teacher:	Ok. You can start with 1.1. (The teacher places this sequence on the board.)

Unlike the previous task where the first two numbers in the sequence were given, in this task, two numbers are given but are not placed in any specific order. In essence, this task as well as the previous task, are examples of what Sullivan, Warren, and White (2000) termed a content-specific open-ended task. Both tasks have a starting point but an open goal. While students have to build a sequence, the type of sequence, the types of jumps, and the length of the sequence are not given. The second task has a greater degree of openness in that the starting point is also undetermined. These tasks foster activities such as investigating, creating, and communicating and often require creative thinking. In the above segment, the teacher takes advantage of the situation in order to promote flexibility. In other words, she seems to be less interested in promoting fluency and more interested in trying to encourage the students to think of various ways of placing the numbers. Moving in an entirely different direction from the ones suggested by the students, she raises another suggestion:

Teacher:	I have another idea. You can expand the numbers. (The teacher writes on the board 0.20, leaves a lot of space, and then writes 1.10)
Tomer:	0.9
Shay:	Nine and a half.
Teacher:	0.90 so the expansion is by 10 and then I can do jumps of 0.45. Is that allowed?
Tomer:	Yes.

First, looking at the different solutions to this problem, we may count four solutions where each solution stems from a very different way of combining the numbers into a sequence. The last solution was presented by the teacher. In this last segment, a shift takes place, not only in the mathematics involved but in the prime initiator of creativity. While in the first part of Episode 2a and in the first part of Episode 2b, various students suggest different solutions. In this last segment, it is the teacher who exhibits creative thinking by expanding the given decimals from tenths to hundredths. Recall that the teacher in the first episode claims that 0.9 is the same as 0.90. In this episode, the teacher specifically expands 0.9 to 0.90 in order to open up the way for many more possibilities and solutions. In other words, she adapts the representation of the number to suit her goals. It is the teacher who displays flexibility, joining the collective effort to come up with various ways of placing the two numbers in a sequence.

That the teacher joins in in the effort to find an original solution is significant also in terms of viewing the classroom as a complex system. Recall that one of the hallmarks of a complex system is its ability to adapt and respond to the environment. Throughout Episodes 2a and 2b, we see this process unfolding by following the interactions among the students and the teacher as well as among the students and themselves. Slowly but surely we see the teacher becoming more and more involved and drawn into the creative process—first by monitoring novel ideas, then by accepting them, and finally becoming totally immersed in the creative activity. We see how the teacher chooses an additional open-ended task more challenging than the previous one and offering additional opportunities for flexible thinking. Then, the teacher insists on continuing the lesson even after the bell rings to signal the end of the period. Finally, she herself comes up with an original solution to the task. The teacher no longer stands apart but has integrated into the classroom system. The system has adapted and responded to the environment. To summarise, the creativity displayed in this episode can be seen to emerge from the adaptations and internal adjustments that evolved during the episode.

Episode 3: How Can Insight Displayed by One Individual be Viewed through the Lens of Complexity Theory?

In this episode, I deviate from the path. Previously, I presented episodes in which it was evident that many participants were involved in the creative process. This episode focuses on one individual and raises several questions regarding how creativity may or may not emerge in a classroom for which it is unclear if a complex system is in place.

The same teacher, Hailey, from the first episode, also taught a fifth grade classroom, which included 32 students, 15 girls and 17 boys. In this episode, Hailey was introducing for the first time subtraction of mixed numerals. The following example is written on the board:

$$\begin{array}{r} 3\frac{1}{2} \\ -1\frac{1}{2} \\ \hline \end{array}$$

Teacher: Let's think together. We'll solve this problem in column form. What do I have to do?

(Many students raise their hands.)

Ian: One half is three-sixths. Two-thirds is four-sixths.
Teacher: Now, wait a minute. What did Ian do? Raise your hands. What did Ian want to do?
Penny: Expansion.
Teacher: He wants to do expansion so both fractions will have what?
Abe: So, they'll have the same six so that you can solve it. And there is a half which is three out of the whole – uh – six. And two-thirds is 4…
Teacher: So, what is he doing?
Harold: A common denominator.
Teacher: So, what should I write here?
Harold: Three out of six.
Teacher: You lost something on the way.
Miri: The half.
Abe: The three wholes.
Teacher: So, it's three and three-sixths.

The teacher, together with her students, brings the second fraction also to a common denominator and rewrites the problem. The following discussion then ensues:

Teacher: From which side should we begin to solve this problem? From the fractions or the whole numbers?
(Students debate from where to begin.)
Miri: From the fractions.
Teacher: We start to solve this problem from the smallest place value. What does this remind you of? Which other problems do we start from the smallest place value?
Lev: Subtraction and addition (of multi-digit numbers) written in column form.
Teacher: Correct.

The teacher then poses the problem of taking away 4/6 from 3/6 and together with the students they exchange the 3 and 3/6 to 2 and 9/6 and proceed to subtract. To summarise the procedure, the teacher once again reminds the class that subtracting fractions is essentially the same as subtracting whole numbers claiming, "You broke up the whole. Just like we solve subtraction (of multi-digit numbers)… say 33 take away 14… you take from the tens digit and add to the ones digit."

Up until this point, the episode seems devoid of creativity. In addition, it is difficult to view the class as a complex system. The teacher seems to be in control. She has a goal and is working towards that goal. After doing out loud another similar example, a student raises her hand:

Amy: I have a question, but it's not exactly related.
Teacher: That's OK. It doesn't matter [if it's not related].
Amy: Let's say I had the problem 32 take away 34. I would have to do an exchange. You can't do two minus four.
(The teacher writes the example in column form on the board.)

Amy: So can you do the exchange?
(The teacher writes on the board.)

Amy: So, 12 take away four is eight. And then two take away three.
Don: Is minus.
Teacher: Minus one. But this -1 is in the tens digit. So it's minus ten plus eight. Which is?

In the beginning, this lesson seems unrelated to creativity. There is no problem posed or task for the students to implement that might occasion creativity. Seemingly out of the blue, Amy poses a question. She inquires about extending the procedure of subtraction to a new domain, that of negative numbers, a domain not yet introduced in fifth grade. In essence, Amy is employing the rules and practices of a domain (subtraction that requires regrouping) to produce a novel (for her and for the class) variation within the domain content. According to Sriraman (2008), this is one aspect of being creative. It may also be said that Amy raises new questions and possibilities related to the old problem of subtracting, another aspect of creativity. Finally, the time it took for Amy to raise the possibility of extending subtraction with regrouping to negative numbers reminds us of the incubation period that may be considered part of the creative process. In fact, Sriraman (2008) points out that in general, a mathematician's creative process follows the four-stage Gestalt model of preparation, incubation, illumination, and verification. In the above lesson, we see a microcosm of these stages. The teacher prepares the stage by analysing in detail the process of subtracting mixed numerals and relating this to subtraction of multi-digit numbers learned previously. During this time, Amy is quiet. We do not hear her voice, although, we can infer by what comes later, that she was listening and processing what was going on. Following this quiet period, Amy comes up with a question, which in her opinion, is not quite related to the classroom topic. While we cannot know for sure when exactly she came up with her idea, it reminds us of the incubation period followed by the illumination. Next, the teacher helps her verify that indeed her idea is on target.

While different aspects of mathematical creativity were noted in this episode, it is less obvious with this lesson that the class is behaving as a complex system. It is difficult to detect the diversity. The teacher seems to be in control. Where is the organised randomness?

Yet complexity theory is not only about viewing the classroom as a complex system. It is about viewing learning as an emergent process and viewing knowledge as distributed. Recall that a simple system is one that may be deconstructed into its components and where the outcome may be predicted. Amy's insightful question could not have been predicted nor can it be explained without looking at the context in which it took place.

To begin with, the teacher does not merely dictate a procedure. She involves the students at each step. According to Morrison (2008), "In complexity theory, learning becomes a joint voyage of exploration, not simply of recycling given knowledge … The teacher is vital, intervening judiciously to scaffold and create the conditions for learning-through-self-organization and the child's emergent knowledge…" (p. 23). Noticeably, the teacher connects the new procedure to previously learned procedures and emphasises the mathematical principles that are the basis for these procedures. In other words, what is emphasised in this lesson is what Davis and Simmt (2003) termed neighbour interactions, mathematical ideas or insights that interact with each other. Thus, instead of focusing on the interaction between participants, in this episode the focus is on the dynamic interaction and interdependence of ideas. Diversity may be seen in the ideas – subtraction of mixed numerals, subtraction of multi-digit numbers, and subtraction resulting in negative numbers – yet they are similar enough (i.e. redundant) to enable interactions. Finally, while the teacher had a goal and aimed to navigate the lesson and the students' learning, she was open to seemingly unrelated questions. Amy's insightful extension of the mathematical principle behind subtraction with regrouping to a new domain of numbers can be seen to emerge as the boundaries of the lesson are stretched. As such, we may surmise that while there were boundaries, there was also an openness to bend these boundaries and that Amy, and most probably other students as well, were aware of this possibility. In other words, there was organised randomness. To summarise, in this episode it might seem that one individual displays creative thinking. But by viewing the episode through the lens of complexity theory, the individual's creativity can be seen to emerge from the dynamic interaction of ideas in an environment that supports adaptations.

RELATING COMPLEXITY THEORY TO EMERGENT CREATIVITY

In the previous section, complexity theory was used to analyse emergent creativity. Taking a closer look, each episode focused on different aspects of creativity. In addition, although complexity theory in general was used to analyse each episode, different features of this theory are emphasised in different episodes. Is it possible that when certain features of a complex system are emphasised, different aspects of creativity will emerge?

In the first episode, the teacher encouraged fluency by presenting a multiple-solution task and explicitly stating that the task had many solutions. Through the lens of creativity, we saw an emphasis on diversity, both in the solutions and in the different ways students participated in the lesson. While of course a certain amount of redundancy was necessary for the interactions to be effective, it is possible that an emphasis on internal diversity promotes the fluency of ideas—one aspect of mathematical creativity. In both the first and second half of the second episode, the aspects of creativity that are most notable are flexible thinking, which leads to novel solutions. In the first half of the episode, the lens of complexity theory focuses on how the system balances between stability and change. In the second half of the episode, the focus was on the system's adaptation to the environment. Essentially, the system's ability to adapt is a result of the balance between stability and change. Thus, it is possible that change and adaptations lead to novel ideas. In the first two episodes, creativity is evident in a number of classroom participants. In the last episode, creativity is evident with one individual for whom the process of creativity seems to follow the path of preparation, incubation, illumination, and validation. During this episode, the lens of complexity theory focuses on the interactions between ideas mediated by the teacher in conjunction with the students. Perhaps paying meticulous attention to mathematical properties along with focusing on the interaction between these properties lays the groundwork for insightful questions. Perhaps the relative stability promoted by the teacher within the complex system of the classroom allows for individuals to take their time in adapting new knowledge to existing knowledge thus allowing creativity to emerge from the process.

Of course, it is too simplistic to claim that any one single feature of a complex system is responsible for one particular aspect of creativity. In fact, the very idea of decomposing the system into its parts negates one of the basic principles of complexity theory—that the whole is greater than the sum of its parts. However, recognising the classroom as a complex system does not mean we ignore the features of the system. Instead, as exemplified in the episodes, we can use principles of complexity such as internal diversity, redundancy, and decentralised control to organise the classroom in a way that supports the emergence of different aspects of mathematical creativity. The contribution of complexity theory to the study of creativity in the mathematics classroom is not only about viewing the classroom as a complex system, it is about viewing knowledge and creativity as emergent processes and viewing knowledge, and possibly also creativity, as distributed. Teachers should be aware that providing tasks that may occasion creativity is but one step towards promoting mathematical creativity. Creativity cannot be made to happen. However, setting up a classroom environment that encourages diversity, supports interactions among participants and ideas, and allows for a certain amount of instability, may well support the emergence of creativity even when it is not planned for.

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STEVE V. COXON

ON THE EDGE OF CHAOS: ROBOTS IN THE CLASSROOM

Robot is a term first coined in 1920 by Czech playwright Karel Capek from the Czech word for forced labor, *robota* (James & Leon, n.d.). Although once only a playwright's fancy, today's robots labor around the world and beyond, and they are playing increasingly important roles in society. Robots are autonomous machines that respond with motor movements to input from the external world through sensors in accordance with computer programs. From autonomous submarines working to stop a deep sea oil spill disaster, to robotics in industry, surgery, homes, military operations, space exploration, and rescue, robots do work for humans that is monotonous, tiring, dangerous, or beyond human capacity. Even the most complex computer programs are vastly simpler and less chaotic than human thinking and the most complex machines are likewise simple in comparison to living systems. Robots can be seen as increasing order in the world and as very simple in their functioning relative to humans. One may place robots in the far lower right hand corner of the Chaos-Order Continuum (Ambrose, 2009). It is instead student thinking and interactions that I argue in this chapter can be pushed to the Edge of Chaos in constructivist robotics-based educational programs. While robots are themselves arguably simple, students working in groups to design, build, and program robots to solve difficult problems requires complex thinking and interaction quite different from within a traditional classroom setting.

To understand the complexity involved for student thinking and interactions in robotics educational programs as they are explained below within a constructivist context, it is important here to draw a contrast with the traditional classroom setting. Robotics educational programs usually fall into two categories: academic competitions outside of the school day as a series of open-ended and challenging tasks and classroom use of robotics similar to problem-based learning. Both activities are constructivist in nature as children work to construct meaning by working with others with great autonomy, physical materials, and tasks that require higher order thinking processes. Such educational programs lead to much more complex thinking and interactions for students than the traditional classroom in which a teacher and text are seen as the sole sources of information, work is individualised and simplistic in nature with close-ended, single-answer problems, and children are dominated by the teacher to restrict their movements, discussions, and habits. Robotics programs have been fundamentally different from their inception.

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 53–64.

HISTORY AND PROGRAMS

As with other models of classrooms that present an alternative to the traditional characterisation above, such as constructivist classroom models, robotics educational programs have existed longer than many today would expect. The Soviet Union's 1957 launch of Sputnik had such a large impact on American science, technology, engineering, and math (STEM) education (Flanagan, 1979; Super & Bachrach, 1957; Wai, Lubinski, & Benbow, 2009), that it could arguably be considered the impetus for robotics education in the U.S., despite the fact that the first programmable robot had only just been developed (Robots.com, n.d.). Robotics use in the classroom was not immediate, but began just over 20 years after Sputnik. While robots were just becoming common to industry in the 1970s (Robots.com, n.d.), *LEGO* Logo, which connects *LEGO* bricks and motors to the then-popular LOGO programming language, was introduced for children in the early-1980s (Fox, 2007; Logo Foundation, 2000). In contrast with traditional modes of instruction, working with *LEGO* LOGO involved student application of understanding computer programming as opposed to the mere consumption of information. To wit, LOGO inventor Seymour Papert was a protégé of Jean Piaget (MIT Media Lab, 2007).

Still, there is no evidence that the use of robotics in schools was widespread until the advent of *LEGO* MINDSTORMS and the corresponding FIRST *LEGO* League (FLL) competition that began in the late 1990s. Notably, the *LEGO* product line takes its name from Papert's (1980) book *Mindstorms: Children, Computers and Powerful Ideas.* Today, many kits exist for engaging students in robotics including with K'NEX, *LEGO* MINDSTORMS, the T-Bot mechanical arm, and Tetrix, which allow students to build sturdy robots with aircraft-grade aluminum. There are several robotics competitions available to K-12 students at international, national, and regional levels including FIRST Robotics Competition (FRC), Junior FIRST *LEGO* League (Jr.FLL), FLL, Fire Fighting Robot Contest, VEX Robotics, and Carnegie Mellon Mobot Races (Coxon, 2009; Robots.net, n.d.; Tallent-Runnels & Candler-Lotven, 2008). Curriculum units for classroom instruction are available for several of the kits both from some of the companies that produce the kits and from third parties (e.g., Coxon, 2010; Toye & Williams, n.d.).

LEGO MINDSTORMS Kits

The most common robotics kit for both competition and classroom use are the MINDSTORMS sets sold by *LEGO* Group, now in the third generation (EV3). While other kits exist, most are either pre-built robots that children may program or are not actually robots in that they operate by remote control (and therefore not autonomously based on input from the external environment via sensors). The EV3 is an update to the NXT and RCX kits that have been sold since the 1990s. The EV3 includes 541 pieces that, as with other *LEGO* sets, can be combined in a very large number of ways. While robots are simple in comparison to living systems, there is a great deal of complexity here in terms of allowing practically unlimited possibility for student building. Danish mathematicians have demonstrated that six 2 x 4 *LEGO* bricks of the same color can be combined in nearly one billion different ways (Eilers, Abrahamsen, & Durhuus, 2005). The possibilities in combining 541 pieces, most of which are more complex themselves than the 2 x 4 bricks in the above calculation are, for all practical purposes, limitless. Increasing complexity further, the kit includes three to four motors and five sensors: color, gyro, ultrasonic, and two-touch. The sensors allow for various inputs from the external world to lead to motor operations based on computer programs written by children. While instructions for several robots are provided with the kit and hundreds are available online or in books, the number of combinations of pieces is limited only by the user and the problem at hand that robot is engineered by children to solve.

FIRST LEGO League

Competitions are one of the two primary delivery models for the use of robotics kits that I focus on in terms of complexity. The largest competition and the focus of this chapter is the FLL for ages 9-14 utilising the *LEGO* MINDSTORMS kit. The competitions have become widely available and are growing fast. FIRST programs now have a total reach of more than 300,000 K-12 students in more than 70 countries after beginning in a single high school gym with a few dozen students in 1992 (US FIRST, 2013). FLL is an academic competition in which students build robots to manipulate *LEGO* objects based on a real-world science theme. For example, in a recent FLL competition, Power Puzzle, the theme was energy production and use. Participants were required to build and program a robot that could add a solar panel to a house and replace a pick-up truck in its driveway with a fuel cell car—all made from *LEGO* bricks. The competitions have multiple facets. Not only do robots compete, but participants also compete for awards in teamwork, robot design, and a presentation on a public service research project that they conduct before the competition. Each facet of the competition adds greatly to the overall complexity of student thinking and interactions within the program.

Robotics in the Classroom

Increasingly, robotics have been incorporated into science education programs including the school day and in after-school programs other than competitions. Designing, building, and programming robotics is seen as an introduction and inspiration to engage children and adolescents in STEM fields. These fields account for the majority of America's economic growth and tremendous improvement of the human condition (National Academy of Sciences, 2005). Problem-based learning (PBL), such as can be conducted with robotics, is potentially engaging for children including the gifted (Allen, 1996). In PBL, students are given a multi-faceted problem and materials. They are then tasked with solving aspects of the problem through research, experimentation, or engineering (as with *LEGO* robotics). Engagement in science learning through real-world problem-solving potentially leads to college majors in STEM fields (Wai, Lubinski, & Benbow, 2009). Meta-analysis has revealed that, with a powerful effect size of 1.48, enhanced context strategies have the highest effect size on achievement of all researched forms of science education (Schroeder, Scott, Tolson, Huang, & Lee, 2007). According to Schroeder et al. (2007), enhanced context strategies include real-world learning and problem-based learning. Robotics is especially appropriate for aiding with both of these enhanced contexts in the classroom. The same meta-analysis found that instructional technology use has a moderate overall effect size of .48 on science achievement. Robotics falls into this category as well. While a smaller effect size, it is still a meaningful one. Some research already exists specifically on the effects of robotics use in classrooms, which will be explored here.

Research on Robotics in the Classroom

As is common to educational technology generally, the research on participant outcomes lags behind usage. The use of robots in education had rarely been researched in K-12 classrooms prior to 2010, but is now growing rapidly. In a search of ERIC database using the keyword "robot," only 35 articles were published between 2000 and 2010. However, between 2010 and 2012, 89 new articles appeared. Only a relative few of these involved K-12 environments with many others used in laboratory settings, medicine, and at the university level. To understand the complexity involved, a selection of those studies that involve K-12 classrooms is presented here.

Of the K-12 studies available, the greatest number involve the FIRST competitions, the largest and most widely distributed robotics programs, followed by those that use the same *MINDSTORMS* sets in the classroom. Perhaps the largest study to date was conducted with participants involved in the FRC, a high school level competition, by the Center for Youth and Communities (CYC) at Brandeis University. Melchior, Cohen, Cutter, and Leavitt (2005) conducted a follow-up survey of participants, coaches, and parents, finding that, in comparison to their peers, FRC participants were 35% more likely to attend college, twice as likely to major in a STEM field, nine times as likely to have an internship during their college freshman year, and even twice as likely to perform community service. Of course, it is unclear if those differences were created by FRC participation or if they are simply indicative of students interested in such competitions. In a similar study from CYC of the FLL, an elementary and middle school level competition, Melchior, Cutter, and Cohen (2004) conducted a survey of FLL participants, coaches, and parents. Of those surveyed, 94% or more believed that FLL participants had increases in such areas as programming skills, understanding of how science and technology can solve real-world problems, problem-solving skills, and leadership skills.

Some studies of FLL suggest that student learning in robotics competitions may generalise to other contexts. In a qualitative study, Petre and Price (2004) observed several robotics competitions in the Seattle area, including FLL, and interviewed participants and coaches. Key themes that emerged included students' desires to complete the tasks, the open-endedness of competition, and the social context. Based on these interviews, the researchers suggest that robotics works effectively to increase understanding of programming and engineering principles, and that this learning was generalisable to other programming and engineering situations.

Geeter, Golder, and Nordin (2002) were attempting to increase the number of FLL teams in Iowa through a university-based program. Based on their observations during this time, they reported that middle school students competing in FLL gained a better understanding of engineering; improved creative thinking, critical thinking, and problem-solving skills; and increased self-confidence levels, interest, and involvement in science and math. The authors suggested that these skills would help students regardless of chosen career path, but do not report on their methods for making these assertions aside from observation during their program.

Robotics has been less well studied in the classroom. The studies that do exist continue to explore robotics education largely through qualitative means. Korchnov and Verner (2010) conducted a qualitative study of student teachers and their pupils involved in a robotics curriculum. They found that self-confidence, learning effort, and coping with learning pressures improved along other variables.

An even smaller amount of research has been quantitative. Williams, Ma, Prejean, Ford, and Lai (2007) found that middle school students using *LEGO* RCX (the predecessor to the NXT) in the classroom improved in physics content knowledge using a pre- and post-assessment. The researchers also looked for student gains in scientific inquiry skills but did not find significant changes. Their study suffered from a small sample with heavy attrition.

Verner (2004) conducted one of the most rigorous studies using Robocell, a robotic arm that can move through five joints. He looked specifically at middle and high school students' (n=128) gains in spatial abilities on 12 spatial tasks. Over the course of treatment with Robocell curriculum, students improved from an average of 46.5% correct on the pre-assessment to 62.4%.

In a similar investigation, Coxon (2012) conducted a controlled intervention study simulating the FLL competition with 75 9-14 year-old gifted students and found significant and meaningful gains on a measure of spatial ability used as a pre- and post-assessment, especially for males (cohen's $d = 0.87$) and groups traditionally underrepresented in gifted programs. The use of robotics may also increase aspects of creativity. In a study of Jr. FLL participants from high poverty schools, Kim & Coxon (2013) found a significant increase in divergent thinking.

ROBOTICS, CONSTRUCTIVISM, AND THE EDGE OF CHAOS

In *The Ubiquity of the Chaos-Order Continuum: Insights from Diverse Academic Disciplines* in this volume, Ambrose makes the argument that ideal democratic dynamics occur at the edge of chaos on the Chaos-Order Continuum. With a balance of both individual freedom and prudent regulation, democratic systems are nurtured. This occurs on the model between anarchy on the extreme chaos end of the spectrum and both left- and right-wing authoritarian governments on the extreme order side of the model.

I argue that this operates the same in schools. The earlier characterisation of the traditional classroom is on the extreme order side of the model: the teacher and text are the sole sources of authority, students work as individuals to answer single-answer, close-ended questions, and student behaviour is tightly controlled as students spend most of their time silently seated at desks to receive information passively. In such classrooms, it is unlikely that students' creative, critical, or other such complex talents will be developed fully. As with government systems in collapse, anarchy may sometimes prevail for the new, underprepared, or substitute teacher. There again, it is unlikely that such complex student talents will be developed. In the middle, approaching the edge of chaos, the ideal classroom for the nurturance of talents within robotics programs can exist with maximal opportunity for working with peers with great autonomy and physical, highly-manipulative materials toward solving complex problems (often called missions in robotics competitions). Whether during the school day or in competition outside of school hours, these programs fit within the constructivist paradigm.

Brooks and Brooks (1993) provide a useful, 12-point framework of constructivist classrooms that is paraphrased as the numbered list below. Such classrooms are ideal for reaching an exquisite balance between order and chaos, including with robotics.

1. Encourage autonomy and initiative. Robotics programs not only allow for student autonomy, they encourage it. Survey research of participants in the FLL program reveals that motivation and student initiative are high (Melchoir et al., 2004). However, teachers who focus on order and domination in the classroom will tend to repeat the example traditional classroom contrast provided. This may be due to a fear of losing control or of chaos. It may also be due to a fear of ignorance. It is impossible to be fully aware of every robot design or even of every programming solution. This stands in contrast to the traditional model in which the teacher is expected to know every answer, albeit to the limited set of content and limited set of answers. If teachers are able to move to the side and provide guidance and coaching as needed, but not provide solutions or allow for failures, they are more likely to find their classrooms on the edge of chaos with student autonomy and initiative at their apex.
2. Use manipulative, interactive, and physical materials. In contrast to the traditional model, robotics programs as constructivist educational models put students in direct and continuous contact with physical materials. While the act of programming alone is an abstract activity, the physical nature of robotics makes such sets ideal tools for the classroom. As the pathways through which students interact with the materials are both without limits of possibility and with an ultimate purpose in a problem to be solved, an exquisite balance between

order and chaos may be achieved.

3. Use cognitive terminology. Cognitive terminology, such as “create” and “evaluate” as well as other academic language is made tangible for children through the use of robotics. Students must both create and evaluate to produce robots that may successfully complete tasks, and these terms can be further engrained through the use of engineering design loops. Strategies for problem solving become useful and through repeated use may become habits of mind for even young children. Such work and terminology interlace and likely become normal facets of participants’ vocabulary as they work on the edge of chaos.
4. Student needs drive lessons, strategies, and content. In the traditional classroom example, content, lessons, and teaching strategies are decided ahead of time by policy makers far removed and with no teaching experience or significant understanding of educational systems, research, or philosophy. Lessons are relatively fixed and unalterable and they are unrelated to individual student learning in the classroom. In the constructivist robotics program, lessons on programming or engineering principles may be taught as needed: by the teacher, a guest expert, or students who have discovered or sought needed knowledge through their own initiative. Strategies are shifted based on constant assessment by student teams or their coaches on reaching goals toward having the robot solve challenges. The teacher is not necessarily the expert on all aspects and student learning may quickly surpass the teacher’s knowledge. This is desired and arguably the ultimate goal of education. If the teacher was always to be the sole font of knowledge, with students never to surpass this level, the best student would be limited to something just shy of the teacher. Instead, the constructivist robotics classroom is a launching point for student learning: an aerie, not a cage. With this understanding on behalf of the teacher, much more is possible and the focus is reversed from a concern over what students do not know to what expertise is accruing.
5. Teachers discover students’ understandings of concepts before sharing their own. Following directly from number 4, teachers do not make assumptions about student conceptual development beforehand, but come to understand each student’s understanding before sharing their own. It may even be unnecessary for the teacher to share as students may either already have an understanding of the concept at hand or develop one through experience with the materials and process. Moreover, when students do not have a well-developed understanding of a concept or hold a misconception, it is likely better for the teacher to guide the students to better understanding through questioning and continued engagement in the robotics activities. For example, a common student misconception is that when a robot is not functioning as desired, it is acting “weird” or “crazy” and that its “behaviour” is based on luck and not within student control. A teacher might guide the student reasoning by questioning physical or programming issues that may have led to the problems, such as a weak battery, loose wheel, or change in conditions that affect a sensor’s input (e.g., lighting with a light

sensor). In this way, the teacher serves as a coach in contrast to the traditional example of a teacher serving as a one-way output of knowledge. In the latter example, the student would merely be wrong and the teacher would provide the answer, leading to more order, but less conceptual development.

6. Encourage students to engage in discussion. Students in robotics programs usually work in pairs or small groups and must work together in order to accomplish their goals. Likewise, a teacher acting as a coach, as in the previous example, must necessarily play a two-way role both listening and using what is heard to question. In both places, the communication is open-ended and not fixed, allowing for a vacillation between order and chaos. A classroom focused on order alone, where the teacher provides ready solutions to the problems and assumes that student thinking is limited and simplistic, is unlikely to generate innovative ideas and solutions to solve the problems set out for the robot. Instead, the traditional, order-focused teacher asks questions with single answers to which students can be either right or wrong.
7. Encourage student inquiry. While the previous examples involve teacher questioning, students are likewise encouraged to question in the constructivist robotics program. They should question their teammates, experts, and the teacher. What are alternative approaches to solve this challenge? Is there a more efficient way to program this? How will other tasks or missions be affected if I redesign my robot for this new challenge? Questions might be more metacognitive as well, and can be encouraged by the teacher. For example, how is this process like what engineers face in the real world? Students from classrooms more closely associated with the traditional example might need encouragement. Such questions in that model may be discouraged or at least downplayed, if they even come up at all in such a mentally limiting circumstance.
8. Seek elaboration from students. Stemming from inquiry is the need to evoke elaboration. In particular, students whose earlier education was within the traditional system may not generate elaborative answers. Such classrooms do not encourage them or model the complexity otherwise inherent in engaged learning. In general, American children are becoming less creative, with the strongest loss being their ability to elaborate upon their ideas (Kim, 2011). Kim and Coxon (2013) offer three likely possibilities for this loss: nationalised minimum competency standards and the associated single-answer tests, video game play and video game addiction, and television. The evidence of excessive television watching's negative impact on children both in terms of cognitive and health aspects is especially strong. American children ages 2–12 watch around 30 hours of television per week on average, varying a bit by age (McDonough, 2009). The television is on during meals in about two-thirds of American households and on for every waking hour in more than a third (Rideout, Foehr, & Roberts, 2010). At 30 hours per week, an average American child watches about 25,000 hours of television between the ages of 2 and 18, or about three out of 17 years between infancy and adulthood. This is greatly more than the

approximately two years of total time in school over the course of the 13 years between kindergarten and 12th grade. The effects of this appear almost entirely negative. Television watchers begin reading later and read less well, are less active and more likely to suffer from ill-health, have decreased attention spans—arguably a key facet in the ability to elaborate and engage in fewer creative activities (American Academy of Pediatrics, 2001; Anderson et al., 2001; Lillard & Peterson, 2011; Rideout, Vandewater, & Wartella, 2003; Tomopoulos et al., 2010; Vandewater, Bickham & Lee, 2006). Students from households that allow this may require more prodding from the teacher to elaborate on their ideas, to experiment, and to begin to think for themselves.

9. Engage students in experiences that might engender contradictions. Drawing on the earlier discussions on conceptual understanding, students with misconceptions and under-developed conceptions, such as the example of why a robot may not be functioning as anticipated, need these experiences that contradict their original idea or hypothesis. In the robotics classroom, there is a constant testing of ideas and experiencing failure. One can build, program, and test through repeated iterations without finding success with the very tangible, physical robot. This is in contrast to the traditional classroom in which there is a single set of correct answers and the basis is abstract rather than physical. Even in the best traditional classrooms where students might be allowed to conduct an experiment after reading about a principle in their science text, the experiment is not student-developed, but instead a series of steps to be followed. If followed correctly, the student arrives at a known answer. If the experiment ends without the expected result, it is considered a summative failure instead of a potential discovery or first iteration of a continuing process. In this manner, the student is acting as a technician and not a scientist. With robotics, when students are allowed to engage in problem solving without an enforced set of instructions, they will likely fail to achieve their goals many times before finding success, and likely have to continue to refine their robot through many more iterations to increase its reliability.
10. Allow wait time after posing questions. Provide time for students to construct meaning. The wait time suggestion is certainly a valid one within robotics, fitting well within the sections on questioning, inquiry, and discussion all discussed above. Time to work is an essential factor in complex learning beyond just wait time after questions. Time is often ignored in traditional classroom settings where the clock is a cruel overseer. Students need many hours to participate in robotics programs, often 40 or more to complete a PBL unit or to prepare for a competition (Coxon, 2009), and this time is better segmented in two to four hour blocks. Within the 50 minute time blocks often allotted to children in schools, cooperative projects in which students must engineer and program a robot to perform complex tasks on open-ended problems where success might be found only after dozens of iterations do not fit well. Wait time in questioning allows for student thought, much more necessary in a complex constructivist environment

than in a single-answer traditional classroom where the “best” students are the fastest to blurt out memorised answers. Students need a wealth of time to construct understanding.

11. Nurture students’ natural curiosity. With obvious delight, babies experiment with gravity through repeated iterations of food dropping and watching items hit the floor. Toddlers find endless joy in sand and water play, and kindergarteners bubble with excitement when exploring a creek. Schools can do much to nurture curiosity, but seem just as able—and more likely—to hamper it. The constructivist classroom on the edge of chaos, including with robotics programs, seems a particularly apt way to continue to nurture curiosity. As students have autonomy and time with materials, in discussion, and in working with peers, it seems more likely that curiosity will be maintained or extended. This is in stark contrast with the traditional classroom where there is little to be curious about given its focus on what is known rather than on what is still to be created or discovered and on the way the world works in the past and present and not on how it might be. There is little to be explored within the traditional context, limited to the abstract, the knowledge of the teacher and the finite text.

CONCLUSION

The edge of chaos is a fine line between highly controlled educational programs on one extreme and anarchistic programs on the other. The edge serves as a place where students may generate creative ideas and elaborate upon them, increase autonomy, motivation, and curiosity, and move toward higher, more complex levels in their development. A constructivist educational program is an ideal setting for this to occur, and robotics programs offer considerable possibility within such settings to move student thinking and interactions into deeper complexity and toward to edge of chaos. Students in such situations likely improve upon skills useful across domains, particularly in the STEM fields, including problem solving, spatial ability, and aspects of creativity. Such situations mimic well the most challenging professional fields, including the sciences and engineering, far more than do the traditional educational programs. Such constructivist programs should be our goal if we are to prepare students to think complexly and generate solutions to their future world’s emerging problems.

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SECTION 3

INTERDISCIPLINARY PERSPECTIVES ON CREATIVE COMPLEXITY

DON AMBROSE

THE UBIQUITY OF THE CHAOS-ORDER CONTINUUM: INSIGHTS FROM DIVERSE ACADEMIC DISCIPLINES

When considering the extent to which complexity theory applies to diverse phenomena it is interesting to consider the structure and dynamics of various academic disciplines. Epistemological frameworks and problem-solving heuristics can differ markedly when one passes through the border separating one discipline from another. Questions arise about the ways in which complex adaptive systems structure themselves and operate when viewed through differing disciplinary lenses.

For several decades scholars in a wide variety of disciplines have been captivated by complexity theory (e.g., Anteneodo & da Luz, 2010; Axelrod, 1997; Bleakley, 2010; Corning, 2005; Cowan, Pines, & Meltzer, 1999; Doll, 2012; Gershenson, 2012; Geyer, 2007; Guastello, 1995; Holland, 1995, 2006; Jervis, 1997; Kauffman, 2002; Lizier, 2012; Mazzocchi, 2012; Miller & Page, 2007; Morowitz, 2004; Packard, 1988; Ping, 2010; Porter & Derry, 2012; Prigogine & Stengers, 1984; Pullman, 1996; Solé, 2011; Spivey, 2008; Strogatz, 2003; Watts, 1999). This body of theory is intriguing because it has broad scope, applying to very diverse phenomena and revealing patterns of similarity in the dynamics of complex adaptive systems ranging from the human mind-brain to the behaviour of other biological systems at the micro-levels, to populations of animals in ecosystems, and beyond.

Some scholars have been applying complexity theory more directly to the workings of the human mind and their insights can contribute to our understanding of giftedness, talent development, and creativity. For example, Richards (2001, 2010) used chaos theory as an analytic framework for scrutinising divergent thinking in creativity. Others have employed chaos theory and complexity theory more broadly by analysing a wide variety of constructs pertaining to creative thought and action while making the case that ideas from this body of theory can improve our understanding of giftedness and creativity (see Dai & Renzulli, 2008; Sterling, 1992). Spivey (2008) argued that psychological studies of information processing are somewhat limited because they rely on the computer metaphor of mind and pay insufficient heed to constructs from complexity theory.

In recognition of these initiatives, this chapter borrows *the edge of chaos hypothesis,* a helpful construct developed by complexity theorists Langton and Packard (see Kauffman, 1995; Langton, 1990; Packard, 1988; Waldrop, 1992), portrays it in the form of a model—the *chaos-order continuum* (see Ambrose, 1995b; also see Rea's, 2003, OEC continuum), and then employs it to analyse diverse phenomena in the

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 67–86.

socioeconomic, cultural, and academic environments that influence the aspiration discovery and talent development of gifted, creative young people. Figure 1 shows the structure and dynamics of the chaos-order continuum. The vertical dimension of the model shows levels of complexity that a complex adaptive system can achieve through its interactions with an environment. At the lowest levels, the system is very simple and it becomes much more complex as it rises on the vertical dimension. In general, the achievement of complexity is a desirable state. In the case of the human brain-mind, for example, simplicity on the model can represent vacuous-chaotic or rigid-dogmatic thinking whereas complexity on the model represents higher-order, creative and nuanced critical thinking.

The horizontal dimension of the model shows a continuum with extreme chaos at one end and extreme order at the other. The edge of chaos is a position in the middle of this continuum where a complex adaptive system can find a promising, productive, exquisite balance between chaos and order. It is along the edge of chaos that a system is best able to generate highly complex, productive behaviour and elevate itself toward higher levels of complex development. Note that the edge of chaos has an irregular, double-ended arrow at the top of the model pointing both toward chaos and order. This signifies that the edge vacillates unpredictably in the mid-range of the continuum due to minor fluctuations in the environment where the complex adaptive system is embedded. At one moment the edge might be accessible a little more toward chaos, and at another moment it might be found a little more toward order. Consequently, finding the edge of chaos is not an exact science.

Since the emergence of the edge of chaos hypothesis (Langton, 1990; Packard, 1988), it has been applied in diverse ways in multiple disciplines. There are some intriguing examples. The hypothesis could help political scientists move their field forward by challenging dominant Newtonian-influenced conceptual frameworks with insights from complexity theory (Ma, 2007). Neural networks seem to exhibit some dynamics aligning with movement toward the edge of chaos (Boedecker, Obst, Lizier, Mayer, & Asada, 2012; Toyoizumi & Abbott, 2011). The edge of chaos also has been applied in sociological studies of communication dynamics (Fontdevila, Opazo, & White, 2011); in transdisciplinary analyses of life processes at multiple levels of analysis (Anteneodo & da Luz, 2010); in discussions of psychological well-being (Robbins, 2012); in reconceptualisations of international foreign aid policy (Ramalingan, 2013); and in analyses of the distribution of interpersonal power in classroom interactions (Harjunen, 2011).

Before proceeding, a caveat is in order because there has been some criticism of possible overgeneralisation of the edge of chaos hypothesis. For example, while noting the value and potential of the hypothesis, Mitchell, Crutchfield, and Hraber (1994) found some conflicting experimental results and recommended some degree of caution when applying it to the dynamics of complex adaptive systems (also see Lizier, 2012). In essence, the edge of chaos should be viewed as an analytic model that can reveal helpful but tentative insights worth pursuing in subsequent research.

It is in this spirit that I engage in the interdisciplinary survey of phenomena that seem to fit the edge of chaos model.

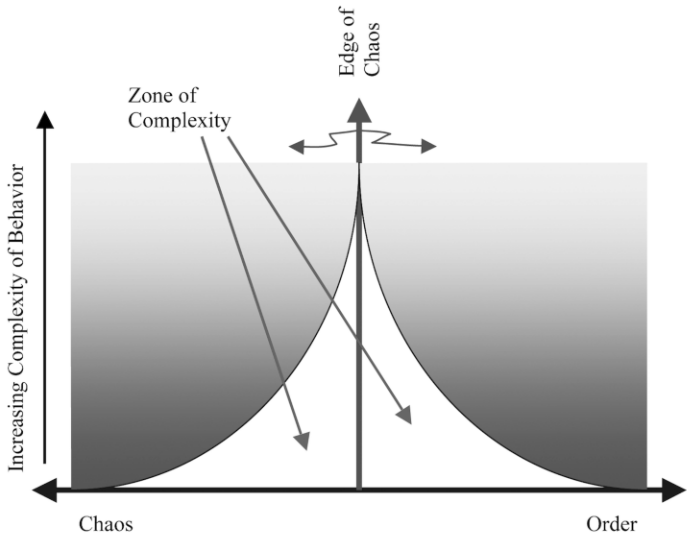

Figure 1. The Chaos-Order Continuum (derived from Ambrose, 1995b).

In the sections to come, the chaos-order continuum is used as an analytic tool for scrutiny of various large-scale contexts that influence the aspiration discovery and talent development of gifted, creative young people. These contexts include regional and national economies, political systems, monotheistic religions, corporate and governmental organisations, various academic disciplines, and the hierarchy of the sciences.

ECONOMIC-IDEOLOGICAL FORCES

Fertile economic conditions must be in place for individuals to discover high-level aspirations and to develop the skills, talents, and knowledge bases required for the pursuit of those aspirations. The chaos-order continuum comes into play in the dynamics of regional, national, and global economic systems as well as the ideological frameworks that strongly influence economies. Although economics has been dominated by a particular theoretical framework—neoclassical theory (see Friedman, 1962, 1975; Hayek, 1944), economies have shifted from time to time along the chaos-order continuum.

From an economic standpoint, the communist governments of the 20th century that were inspired by the ideas of Karl Marx and Frederick Engels (see Marx, 1968), were designed to control the dynamics of economies so that self-serving, aristocratic elites could not commandeer economies for their own personal benefit while leaving the masses exploited and impoverished. Communism arose in reaction to the exploitative economic and political abuses of the masses by the oppressive monarchies and landed aristocracies that Europe had suffered for centuries prior to the early 1900s.

In contrast during recent decades the American economy has been shaped by neoclassical economic theory and its ideological cousin—neoliberalism. Neoclassical economics and neoliberal ideology promote the freedom of the individual to make self-serving decisions with minimal interference from governmental regulation. The intent is to encourage innovation and to maximise individual liberty (Friedman, 1962, 1975; Hayek, 1944; Lal, 2006; Nozick, 1974). Primary assumptions are that free markets generate the best economic outcomes because multitudes of self-interested rational actors making countless economic decisions unfettered by governmental policies will generate high levels of prosperity and maximise economic growth through the workings of Adam Smith's (1776/1937) hypothetical invisible hand of the marketplace.

Mapping these large-scale economic dynamics onto the chaos-order continuum reveals some interesting patterns. Twentieth-century communist economies were centrally controlled. For example, the state-owned economy of the Soviet Union ran on the basis of high-impact decisions made in Moscow. Central decision makers manipulated the allocation of resources, the distribution of talent into various sectors of the economy, and the nature of the output of the economy on both regional and national levels.

Centralised, national decision making such as this put the Soviet economy on the extreme order end of the chaos-order continuum and largely prevented the development of vibrant, complex, economic innovation. Those with creative, innovative inclinations were not free to develop their aspirations to the fullest. From a talent-development standpoint, the abilities of many of the best and brightest in the Soviet Union were left to die on the vine. Of course through the dynamics of central planning, the Soviet Union did develop considerable mathematical and scientific talent by recognising promising students early in their school careers and shifting them onto STEM (science, technology, engineering, mathematics) educational tracks with or without their consent (Mathews, 1982); however, the economy suffered overall. Consumer goods were lacking and efforts to develop prosperity were anemic. As with most complex adaptive systems that lock themselves into the extreme order end of the chaos-order continuum, vibrant complexity in the form of a strong, complex economy, did not develop in centrally controlled communist systems.

In contrast, the globalised economy of the last several decades, especially the American sector of the world economy, has been following a very different path. Based on the ideas of neoclassical economists (e.g., Friedman, 1962, 1975; Hayek, 1944) and neoliberal ideologues (e.g., Lal, 2006; Nozick, 1974), the late 20th- and early 21st-century globalised economy has been dominated by laissez-faire ideas.

Neoclassical economic theory and neoliberal ideology have been stripping away governmental regulations, especially in nations that have been most influenced by the neoclassicists (e.g., the United States; to some extent the United Kingdom). In overzealous efforts to maximise individual freedom for self-centred rational actors, influential neoliberals employing neoclassical economic ideas have torn down environmental regulations, employment protections, and social programs for the needy, thereby generating an environment where creative but selfish, unscrupulous, near-psychopaths and indolent inheritors of privilege have monopolised the levers of power and drained away much of the wealth from the vast majority (Ambrose, 2012; Hacker & Pierson, 2010; Madrick, 2011; Stiglitz, 2010, 2012). Hence, we see the recent occupy Wall Street protests and the economic complaints from the 99%.

This deregulated, pseudo-Darwinian economic system is positioned at the extreme chaos end of the chaos-order continuum due to its emphasis on deregulation and laissez-faire, individual freedom. Leaving the vast majority in tenuous economic circumstances comparable to those suffered by the masses in 20th-century communist economies at the other end of the continuum, it lacks productive complexity because the wealth it generates is usurped increasingly by an unscrupulous, privileged few.

Is it possible for economies to find the productive zone of complexity in the middle of the continuum? Recently, leading economists, Nobel laureates among them, have been dissenting from the orthodoxy of the neoclassicists and arguing that returning to some form of Keynesian economics would be far preferable to the current state of affairs (see Krugman, 2008; Madrick, 2011; Quiggin, 2010; Stiglitz, 2010). Keynesianism promotes the use of prudent regulation to prevent abuses by powerful, near psychopathic economic actors, and encourages government investment in the economy during times of serious economic downturn. A Keynesian approach to the economy fits in the middle of the chaos-order continuum, somewhere near the edge of chaos where productive complexity emerges because it balances the need for some order in the form of prudent regulation with the need for some chaos in the form of economic freedom. It enables innovation to arise within a climate of fairness and security. Nations more aligned with Keynesian economics than with neoclassical economic theory tend to develop vibrant but fairer economies and a higher quality of life for the vast majority of their citizens (Stiglitz, 2010, 2012; Wilkinson & Picket, 2009).

These various economic positions on the chaos-order continuum also exert differing influences on the aspiration discovery and talent development of gifted young people. The excessive order of 20th-century communist systems generated insufficient economic opportunities and exerted excessive control over the aspirations of the gifted. As mentioned, there were some outlets for aspiration development, especially for those inclined to pursue careers in STEM fields, but the aspirational decisions often were made *for* the children, not *by* them.

There is more opportunity for the discovery of aspirations in neoclassical economic conditions, at least for the privileged; however, significant distortional and suppressive effects are at work. In spite of persistent, utopian, neoliberal rhetoric to the contrary, the United States is not a very good place to pursue the American dream in comparison with other developed nations. According to Wilkinson and Pickett (2009), young people in the more unequal developed nations enjoy much less social mobility than their peers in more egalitarian nations. Social mobility is the chance that a child will be able to surpass the socioeconomic status of her or his parents throughout the course of a lifetime. Of all the developed nations in the Wilkinson and Pickett studies, the United States is the most unequal. It also is the developed nation most strongly aligned with neoclassical economic theory and neoliberal ideology. In view of this, it seems that the chaos of excessive neoliberal, unfettered market systems inhibits the productive complexity of high-level aspiration discovery and talent development for large numbers of their citizens. The privileged few have virtually unlimited resources and opportunities for aspiration discovery and talent development in neoclassical economic systems. However, the utopian enthusiasm for the self-serving nature of perfectly rational actors portrayed in neoclassical economic models and neoliberal ideology encourages those who can discover aspirations and develop talents to do so for self-centred, materialistic, vainglorious purposes without the intrusion of complex, ethical, or altruistic considerations. Unless one is an extreme Hobbesian pessimist about human nature, this appears to be a distortion of aspiration development for gifted, privileged young people.

POLITICAL DYNAMICS: DEMOCRATIC GROWTH AND EROSION

Similar phenomena emerge in the political dimensions of societies because ideology contributes to both economic and political decision making. The governments of nations can locate themselves on the chaos-order continuum and shift from one political position to another over the course of time. Anarchic, democratic, and totalitarian governments situate themselves in very different parts of the continuum.

Political anarchy occurs when there is no political authority with the power to establish and maintain the rule of law (Walzer, 2001). Throughout history, anarchy has arisen temporarily during revolutions and other shifts of power or when civilisations are collapsing (Diamond, 2004). An anarchic nation politically fits into the extreme chaos end of the chaos-order continuum. Its policymaking apparatus is insufficient or completely absent so its citizens must endure a lack of legal protection from the rapacious whims of the most creatively ambitious, ruthless, and psychopathic among them. The complexity of highly effective democratic governance cannot emerge easily in such conditions.

In contrast, a totalitarian government establishes firm control over the policymaking apparatus and legal frameworks of the nation. It also relies on a tightly controlled media that becomes a propaganda outlet responsible for indoctrinating and controlling the minds of a compliant citizenry.

Interestingly, totalitarianism can arise in strikingly opposite ways; both of which tend to occur when the population of a nation is excessively polarised, and one ideological group comes to dominate its opponents (Bermeo, 2003). In one scenario, the left-wing ideals of communal solidarity, distributive justice (spreading the wealth throughout the population) and centralised socioeconomic regulation are taken too far to the point where the nation suffers democratic erosion and slides down a slippery slope toward totalitarianism. At the bottom of this ideological-political descent, a small, dogmatic elite comes to exert total control over the sociopolitical system. The nations of the 20th-century communist bloc were examples of these dynamics.

The same process of democratic erosion can occur when the right-wing ideals of individualism, economic freedom, limited government, and dogmatic favoritism of a particular population group (a class, race, or ethnicity) are taken too far and enable private or corporate interests to run roughshod over the needs and rights of the citizenry. Here again, a small, dogmatic elite comes to control the important decision making in the nation. The Pinochet regime in Chile was an example of right-wing totalitarianism that exerted firm political control for the benefit of corporate interests and the established elite (Ensalaco, 2005).

The eminent social scientist Sheldon Wolin (2008) pointed out that corporate dominance now threatens the world and is generating democratic erosion that is moving us toward a new form of political domination that he terms *inverted totalitarianism*. This system is less flagrant than Nazi Germany or the Stalinist Soviet Union. Jackbooted troops are not marching through the streets en masse, and large-scale concentration camps are not evident. But the system exerts increasingly firm control for the benefit of a small elite and is becoming totalitarian nonetheless.

In spite of their polar-opposite belief systems, both forms of totalitarianism, left- and right-wing, end up at the same position in the extreme order end of the chaos-order continuum. In totalitarian governments, a dictator or a firmly entrenched bureaucratic left-wing oligarchy or a right-wing plutocratic elite provides excessive order by exerting firm control over the policymaking and legal systems. The media is controlled by those in power and distributes very little substantive information. Instead, the media persistently spews forth propaganda to bolster the firm control of the governing elite.

Both left-wing and right-wing totalitarian systems are saturated with dogmatism. A dogmatic belief system establishes and maintains excessive order because it is nearly impenetrable and firmly resists change even when compelling counter-evidence comes to the fore (see Ambrose & Sternberg, 2012; Ambrose, Sternberg, & Sriraman, 2012). Maintaining the dogmatism of the official belief system is the primary function of the elite-controlled media in a totalitarian system.

A nation can establish healthy democratic governance when it avoids polarisation, dogmatism, and the excessive ambition of self-serving elites by establishing the conditions necessary for democratic growth. These conditions include widespread deliberative citizen participation, epistemic power, and prudent regulation of the socioeconomic system (see Ambrose, 2005; Gutmann, 2003). The government strives to be transparent, legitimate, and inclusive by encouraging the informed, deliberative participation of all citizens. It maintains transparency by establishing a hands-off attitude toward the media, thereby encouraging the emergence of objective, ethical, investigative journalism. Such journalism highlights corruption wherever it may be found, including in the systems of government (Belsey, 1998). Consequently, it protects the transparency of the governmental system, making it more legitimate in the eyes of the populace and making citizens' participation in governance more likely. A well-informed citizenry enjoys epistemic power that entails in-depth knowledge about the sociopolitical system, warts and all. Taken together, these nurturing conditions for democratic growth establish complex, productive democratic dynamics in the political system and thereby position a nation in the zone of complexity near the edge of chaos on the chaos-order continuum. The exquisite balance between individual freedom and prudent regulation by a government that respects and relies on its citizenry maps onto the exquisite balance between chaos and order on the continuum.

While a perfect, optimal democracy is possible, it has never yet been achieved on the large scale; however, some democracies come closer to it than others, and some are moving away from the ideal. For example, according to leading political scientists Hacker and Pierson (2005), the United States has been shifting rightward on an ideological continuum away from moderate positions toward right-wing extremism. For the past several decades, right-wing ideology has dominated, and the exquisite ideological balance required for optimal democracy is being threatened. As a consequence, the United States has been moving vigorously toward Wolin's (2008) inverted totalitarianism on the excessive order end of the chaos-order continuum. Elite corporate interests have commandeered the levers of power in federal and state governments. The shortsighted Supreme Court *Citizens United* decision that enabled wealthy, powerful interests to spend virtually unlimited amounts of money to influence or even determine the results of elections and the direction of policy (see Hacker & Pierson, 2010), accelerated this movement into the inverted totalitarian, firm-corporate-control region of the chaos-order continuum.

A model of democratic growth and erosion (Ambrose, 2005) made it possible to perceive the effects of democratic vibrancy or weakness on the aspiration discovery and talent development of gifted young people. Mapping totalitarian and democratic governments onto the chaos-order continuum makes it possible to view the effects of the political dimensions of the continuum on the development of high ability.

Gifted young people in totalitarian regimes suffer from severe damage to, and distortion of, their development. The children of privileged insiders enjoy strong support for their aspiration discovery and talent development; however, their development is pushed toward grandiose, insidiously warped, hollow, egoistic-individualistic gratification (Ambrose, 2005). Simultaneously, the non-privileged vast majority of gifted young people in a totalitarian nation suffer from crushed aspirations and the concomitant stunting of talent development and self-fulfillment. The crushing of aspirations and talents inhibits the development of cognitive complexity, thus approximating the excessive simplicity at the extreme order end of the continuum.

In strong contrast, the aspiration discovery and talent development of the gifted in nations with healthy democratic governance are much more vigorous and complex. The vast majority of young people in healthy democracies enjoy widespread support and encouragement for the discovery of interests and long-term aspirations and for the talent development needed for pursuing those aspirations. This generates rich opportunities for vigorous talent development and altruistic self-fulfillment as opposed to the distorted, self-centred gratification achieved by gifted children of the privileged elite in totalitarian systems. According to Mele (2001), a philosopher, the richest forms of self-fulfillment are flavoured with altruism and do not entail hyper-individualistic vainglory. Consequently, a healthy democracy positioned near the edge of chaos in the zone of complexity on the chaos-order continuum encourages richer forms of self-fulfillment and promotes widespread, positive, complex cognitive and ethical development.

These political and economic dimensions of the chaos-order continuum arguably are its most important dimensions when it comes to the development or suppression of aspiration discovery and talent development among gifted young people because they exert such strong influences over large populations worldwide. There are, however, additional ways in which the continuum influences the development of the gifted.

CULTURAL DYNAMICS: RELIGIOUS CONFLICTS

While economic and political structures in a society can influence the development of gifted young people by establishing excessive chaos, excessive order, or productive complexity in large-scale socioeconomic contexts, the religious dimensions of culture also can shape aspiration discovery and talent development. Monotheistic religions such as Christianity, Islam, and Judaism have provided considerable sustenance and support for individual identity development and generous, altruistic behaviour over the course of many centuries. However, they also have been responsible for much suffering and persecution throughout history (Moore, 2000; Stark, 2003a, 2003b) because they provide a strong sense of purpose and unity for a population, and this can encourage a dominant majority to persecute a minority made up of outsiders or nonbelievers who are not adherents to the dominant faith. Due to the intensity of the shared religious identity, outsiders can be perceived as impure and can become targets for attack.

According to Stark (2003a), such conflict isn't necessary because monotheistic groups can coexist for sustained periods of time as long as opportunities to dominate do not arise:

> Pluralism can be quite stable and even civil, so long as there are many religious organisations, none of them very powerful. However, if there exist only a few very powerful religious groups, intense conflicts must ensue as each attempts to suppress the other(s). (p. 119)

Thus, it seems that a group's urge to force its own orthodoxy on others can be balanced somewhat by the desire for self-preservation and peaceful coexistence. But the urge for religious dominance tends to break through frequently and causes widespread strife.

Moore (2000) revealed that the religions of Asian cultures did not generate similar, large-scale, identity-based attacks on minorities until they were influenced by Western cultures. It is the powerful sense of purpose and unity that provides the strong sense of "us versus them," that encourages these large-scale conflicts.

From the viewpoint of the chaos-order continuum, the strong feeling of identity, purpose, and unity derived from a monotheistic religion can be conceived of as satisfying a craving for stability and order in a confusing, threat-filled world. The craving for order is even more powerful in the case of religious fundamentalism. According to Marty and Appleby (1994), extremist fundamentalism emerges and strengthens in a society when a population feels threatened politically, economically, or culturally. In such conditions, individuals crave stable, secure, unquestioned group identities and cluster together for mutual support in dogmatic, fundamentalist groups. Fundamentalists lock themselves firmly into the extreme order end of the chaos-order continuum. From the viewpoint of a strong believer, a hypothetical lack of religious belief would appear to leave one floundering psychologically at the chaos end of the continuum without a strong identity anchor in a turmoil-generating, threatening world.

The long-term, peaceful, religious coexistence noted by Stark (2003a), which occurs when no single monotheistic group is powerful enough to dominate, appears to require the complexity of inter-group diplomacy and negotiation. Thus, balanced groups of religious populations peacefully tolerating one another through artful diplomacy seem to have found the fine complexity of statecraft near the edge of chaos in the middle of the chaos-order continuum.

Considering the ways that these positions on the continuum can affect the aspiration discovery and talent development of gifted young people is intriguing. Those growing up in conditions of peaceful, multi-faith coexistence might be encouraged to develop aspirations having to do with diplomacy and negotiation. In contrast, those growing up in fundamentalist societies prone to religious conflict might have these diplomatic aspirations suppressed. Instead, they might be encouraged to develop strong, manipulative leadership talents and dogmatic mind sets so they can rise to the apex of their identity groups.

THE STRUCTURE AND OPERATIONS OF ORGANISATIONS

Another dimension of culture is the way that business and governmental organisations structure themselves and function. Some organisations are more hierarchical and predictable than others. Some go through significant transformations or disintegrate when they no longer fit the demands of their environments. In order to gain more understanding of these phenomena, complexity theory has been applied to organisational leadership. For example, leaders can shape the dynamics of the organisations in which they work by influencing organisational identity (Schneider & Somers, 2006). Boal and Schultz (2007) argued that leaders can play important roles in nudging their organisations inward toward the productive edge of chaos on the chaos-order continuum.

According to Ambrose (1995a) organisations can operate like large-scale human brain-mind systems, some of them functioning as intellectually impaired, innovation-suppressing bureaucracies and others functioning as creatively intelligent, postindustrial systems. In an intellectually impaired organisation the leadership is myopic and coercive. Consequently, it strongly suppresses creativity while making somewhat more room for critical thinking. However, most of that critical thought is distorted into cynical naysaying. The affective climate of such an organisation is characterised by anger, frustration, and fear. Habit-bound, innovation-suppressing thought and action play much larger roles than they should in such an organisation. Finally, at the individual level, employees are compartmentalised in cubicle-like environments that inhibit creative communication. The overall result of this unfortunate configuration is an oppressive, stay-the-course mentality that makes the organisation unable to adapt to changing conditions.

Creatively intelligent, post-industrial organisations, on the other hand, enjoy the benefits of visionary, facilitative leadership that encourages employees to generate creative ideas and innovations. This creativity is blended with a healthy propensity for incisive critical thinking that selects the best of the creative ideas and refines them, making them even more effective. The opportunity to buy into and to contribute to an optimistic vision while generating creative and critical thought enables employees to thrive in an affective climate characterised by excitement, pride, and purpose. Habit-bound thinking and traditional procedures are present in the system because every organisation needs to develop automaticity when it comes to mindless but necessary procedures; however, habit bound tradition is a minor element and does not dominate the creative, postindustrial organisation.

The dynamics of these contrasting organisational systems provide very different contexts for the aspiration discovery and talent development of gifted individuals. Here, the gifted individuals under consideration are adults who work in these environments. Those who work in intellectually impaired bureaucracies have little opportunity to think creatively or to buy into a long-term organisational vision; consequently, they are pressured to serve as mindless proles. They are locked into the barren, excessive order end of the chaos-order continuum in the case of autocratic bureaucracies or the equally barren, excessive chaos end of the continuum in the case of directionless organisations with weak, shortsighted leadership. Any aspiration discovery and talent development that occurs must take place outside of the work environment. The most intelligent and talented either will leave these infertile organisations to find better contexts or will find outlets for the pursuit of hobbies that can lead to some form of long-term aspiration development.

Those fortunate enough to work in creatively intelligent postindustrial organisations easily can align their hunger for aspiration discovery and talent development with the rich opportunities provided by work contexts that encourage complex, creative and critical thinking, innovation, and pursuit of long-range, visionary goals. Opportunities to work with like-minded peers on innovative projects can illuminate interests and ignite long-range aspirations that in turn encourage the development of impressive talents over the course of time. This rich, personal growth is indicative of navigation along the edge of chaos in the zone of complexity on the chaos-order continuum.

FINDING THE ZONE OF COMPLEXITY IN ACADEMIC PURSUITS

While the chaos-order continuum exerts considerable influence in the large-scale economic, political, cultural-religious, and organisational arenas it also shows up in the structure and dynamics of academic disciplines. Scholars in some disciplines are pressured to think and act very differently from their peers in other disciplines. In addition, there are misconceptions about the extent to which order prevails in the natural sciences.

Stark Differences in the Structure and Dynamics of Academic Disciplines

Some scholars have deviated from narrow academic pursuits to show interest in the macro-structures of their disciplines. A particularly interesting example of this deviation came from a diverse group of theorists and researchers who collaborated in the exploration and comparison of the structure and dynamics of four disciplines from the social sciences and humanities (Bender & Schorske, 1997).

In this project, scholars of analytic philosophy, economics, political science, and English literature determined that two of these disciplines, analytic philosophy and economics, fit into a pattern characterised as unified, insular, and firmly policed. They are unified because they are dominated by a single conceptual framework (e.g., the rational actor model in neoclassical economics). They are insular because they discourage the importation of constructs from beyond their borders and they tend to ignore any invading constructs that somehow manage to wend their way through their otherwise impenetrable borders. They are firmly policed because the gatekeepers in the field, such as journal editors, tend to reject articles submitted by scholars who don’t align their work closely with the established orthodoxy.

The conformity of unified, insular, firmly policed disciplines reveals their location on the order end of the chaos-order continuum. The danger here is that excessive order in these disciplines might be inhibiting the development of complex theory and research that might be obtained by intermixing with diverse, alternative conceptual frameworks. In terms of aspiration discovery and talent development, gifted young scholars in a unified, insular, firmly policed discipline must toe the line of orthodoxy and inhibit their imaginations in efforts to make their research and theorising conform to established lines of inquiry. This might appeal to scholars who crave order but those with creative, imaginative inclinations might find themselves denigrated as misfits.

The other two disciplines in the Bender and Schorske (1997) analysis, political science and English literature, fit into a very different pattern. They were deemed to be fragmented, porous, contested disciplines. They are fragmented because diverse theoretical perspectives keep emerging. They are porous because they either encourage or cannot prevent invasion by constructs from outside disciplines. They are contested because small, warring camps establish themselves in the research terrain and engage in minor skirmishes with one another. Later analyses carried out by investigators borrowing from the Bender and Schorske framework showed that the fields of creative studies (Ambrose, 2006) and gifted education (Ambrose, VanTassel-Baska, Coleman, & Cross, 2010) also fit the fragmented, porous, contested pattern.

The uncertainty and unpredictability of fragmented, porous, contested disciplines reveals their location on the chaos end of the chaos-order continuum. The problem with this location is that excessive chaos in these disciplines might be preventing progress because theories buffeted by excessive conceptual turbulence cannot establish themselves and grow into robust, productive structures that would move knowledge forward. As for individual aspiration discovery and talent development among gifted, young scholars, those who can tolerate ambiguity in a creative sense might thrive while those who crave certainty and order could find themselves mismatched with their fields.

The Not-So-Solid Certainty of the Natural Sciences and Mathematics

If one were to ask typical, somewhat knowledgeable laypeople about the extent to which mathematics and the natural sciences generate predictability and certainty they likely would conclude that these disciplines do indeed provide solid, bedrock bases for our understanding of reality. Mathematics entails the precision of numbers and the natural sciences entail the certainty of physical laws. Research and scholarly analyses can be found to support these assumptions. For example, Simonton (2012) described the way in which academic disciplines tend to align themselves along a hierarchy of the sciences with the natural sciences at the top, where precision, certainty, and predictability prevail, and the social sciences and humanities falling into various places in the lower reaches of the hierarchy where uncertainty and lack of predictability are found.

But things are not so cut and dried in the hierarchy of the sciences. For example, Byers (2007, 2011), a leading mathematician, reported the results of his inquiries into mathematics as a domain. His conclusions were that mathematical thought and investigation are much less precise, certain, and logical than is commonly believed. While both mathematics and the natural sciences strive for precision and certainty they actually entail much uncertainty and make considerable room for the pursuit of wonder. He went so far as to say that striving too hard for certainty in mathematical and scientific inquiry leads to *sterile certainty,* which means the investigator has imposed excessive, unwarranted conceptual order on the phenomena under scrutiny (Byers, 2011).

The periodic emergence of starkly contrasting scientific paradigms (Kuhn, 1962) reinforces the notion that excessive confidence in the certainty of current scientific knowledge should not be embraced too firmly. Simonton's (2012) analyses of the hierarchy of the sciences add further caution about excessive certainty. He revealed that the great, transformative investigators in the natural sciences at the more precise, certain, top of the hierarchy actually tend to think less like their more pedestrian, confirmation-loving, mechanistic peers in these disciplines and come closer to the thought processes of the more artistic, ambiguity embracing, somewhat qualitative scholars in the disciplines in the mid- and lower reaches of the hierarchy. Einstein's visual-metaphorical thought experiments in physics (see West, 2009) and the artistic, imaginative, visualisation of three-dimensional structures in organic chemistry carried out by Nobel Laureate Robert Burns Woodward (see Woodward, 1989) are specific examples of this phenomenon.

These revelations about the unexpected elements of imprecision and uncertainty in mathematics and the natural sciences can be mapped onto the chaos-order continuum, and they have implications for the aspiration discovery and talent development of gifted young people who are heading toward STEM careers. Common assumptions about the certainty, predictability, and precision of mathematics and the natural sciences would seem to put these disciplines at the order end of the chaos-order continuum. However, in view of Byers' (2007, 2011) insights about the elements of unpredictability and uncertainty that actually reside in mathematical and scientific thought and inquiry there seems to be more of a balance between chaos and order. If so, the best work in mathematics and the natural sciences is located in the very promising, complexity generating space near the edge of chaos in the middle of the chaos-order continuum. For this reason, gifted young people who aspire to be mathematicians or natural scientists can be optimistic about their chances for immersion in careers that will bring them opportunities for complex, engaging, highly motivating creative and critical thinking. They will have chances to discover highly complex, even somewhat artistic patterns in mathematical and scientific phenomena. Unfortunately, those who aim themselves at mathematical and scientific careers because they hope to find comfort in absolute, orderly precision and certainty at the order end of the chaos-order continuum may find themselves mismatched and disappointed.

CONCLUDING THOUGHTS: ANTIDOTES TO ENTRAPMENT AT THE EXTREMES OF THE CHAOS-ORDER CONTINUUM

Most of the ideological, economic, political, cultural, and academic confusion and conflicts discussed in this chapter arise from unwitting entrapment at either the excessive order or excessive chaos ends of the chaos-order continuum. Dogmatism, the absolute belief in the worthiness of one's own position in spite of compelling counter-evidence (see Ambrose & Sternberg, 2012; Ambrose, Sternberg, & Sriraman, 2012), likely is the biggest problem in this regard. Otherwise gifted but dogmatic economists can believe firmly in the accuracy of the rational-actor model that dominates their discipline and traps it within excessive conceptual order even though the model does not map onto economic reality very well (Krugman, 2008; Madrick, 2011; Stiglitz, 2010). Otherwise thoughtful and kind citizens and ideologues can believe firmly that their adherence to *market fundamentalism* (see Stiglitz, 2010) promotes freedom and the greater good when it actually is driving the world simultaneously toward the excessive chaos of free-for-all, exploitative, pseudo-Darwinian economics and the excessive political order of corporate-dominated inverted totalitarianism. The complex, nuanced altruism that impressively resides at the core of monotheistic religions becomes poisoned when spiritual leaders and believers fall prey to the comfort of the excessive order provided by religious fundamentalism. The human-resource talent in organisations dies on the vine when otherwise intelligent organisational leaders are dogmatic about following the excessive order of bureaucratic policies and hierarchical rules. Even in the natural sciences and other academic disciplines dogmatism can prevail when scholars don't understand the contextual pressures imposed by the structure and dynamics of their disciplines. As Elder and Paul (2012) made clear, the gifted and highly intelligent are not immune to dogmatism. In fact, at times they can be more susceptible to dogmatism than their less-able peers because they are more prone to falling in love with their favored ideas.

If we are so vulnerable to entrapment at the extreme ends of the chaos-order continuum, is there much hope for escape when such entrapment occurs? Emphasising higher-order thinking in our education systems might help. Rather than mindlessly and complacently aligning ourselves with shortsighted, dogmatic, superficial educational improvement and accountability systems such as the No Child Left Behind (NCLB) initiative that has dominated American education in the past decade, it would be wiser to strive for a 21st-century educational vision that recognises the problems of excessive order or chaos and the high potential of navigation within the zone of complexity on the chaos-order model. NCLB and similar reform initiatives lock American education into the barren, excessive order end of the continuum because it demands accountability for achievement of superficial educational goals based on the excessive order of misapplied standardised testing. The result is *creaticide,* the systematic killing of creativity in the American education system (Berliner, 2012).

An important element of higher-order thinking is nuanced judgement that entails the ability to avoid polarisation and to see the shades of grey between what others would view as black-and-white, either-or choices (see Resnick, 1987). Individuals able to engage in nuanced judgement would be much less likely to fall prey to dogmatic belief systems or theories that are locked into the extreme ends of the chaos-order continuum. Instead, their tolerance of ambiguity and their ability to explore the shades of grey between polar opposites would make them much more comfortable navigating the nuances of the zone of complexity near the edge of chaos on the continuum.

Escaping the rigidity of binary logic can be helpful in this regard. As a side effect of analytic-philosophical thinking, binary logic is helpful when we are dealing with clearly defined phenomena but it traps us into excluding the middle ground when dealing with more nebulous, complex issues (Nicolescu, 1996). In these cases it establishes artificial simplicity, locking us into the excessive order end of the chaos-order continuum. In contrast, “the logic of the included middle has revealed itself as the ideal tool for the analysis of complexity” (Nicolescu, p 400). Dialectical thinking through which individuals and groups aim for understanding of opposing positions and productive syntheses of those positions (see Ambrose, 2003; Sternberg, 1999, 2001) provides a method for escaping dogmatism and finding the logic of the included middle through nuanced judgement.

Another way to escape dogmatism is to engage in interdisciplinary explorations of complex problems and issues. Page (2007) showed how cognitive diversity generates superior outcomes when groups wrestle with complex problems. Cognitive diversity is present when a group encompasses diverse theories, problem-solving heuristics, and philosophical perspectives. A cognitively diverse team tends to outperform a homogenous team even when the latter team has somewhat superior measured intelligence.

Interdisciplinary work naturally generates cognitive diversity because experts in diverse disciplines brought together around a complex issue or problem (e.g., political or economic development, ideological or religious conflict, difficult scientific phenomena) can bring into play very diverse theories, problem-solving heuristics, and philosophical perspectives. Examples of interdisciplinary cognitive diversity applied to complex issues include recent collaborations by leading scholars exploring morality and ethics (Ambrose & Cross, 2009) and dogmatism (Ambrose & Sternberg, 2012; Ambrose, Sternberg, & Sriraman, 2012). An example of interdisciplinary cognitive diversity emerging not from a group but from an individual comes from Ambrose (2009) who navigated through 87 theories and research findings in 29 academic disciplines, cross-referencing remotely associated constructs to generate creative insights about complex, difficult societal and scholarly issues. These interdisciplinary projects represent attempts to explore the zone of complexity near the edge of chaos on the chaos-order continuum. The cognitive diversity brought to bear in these explorations was a significant advantage in each project.

In view of the ubiquity and apparent influence of the dynamic tensions between excessive chaos and order on diverse phenomena, we should look for ways in which these tensions influence the discovery of aspirations and the development of talents in gifted young people. Although the gifted are not immune to dogmatism (Elder & Paul, 2012), their high-powered minds make them capable of shedding excessive order and chaos when they recognise the dangers of entrapment at those ends of the continuum. With more awareness of the chaos-order continuum and its dynamics, gifted children, adolescents, and college students will be able to develop more productive aspirations that better align with their latent abilities and aim them toward more beneficial impact on the world when they become adults.

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ELIZABETH WATSON

ORGANISATIONAL LEADERSHIP FOR CREATIVITY: THRIVING AT THE EDGE

Several years ago, in a spontaneous, self-organising way, a group of colleagues and I initiated a creative act in our organisation. We generated a series of workshops for ourselves in order to improve our work, engage in problem solving, and learn from each other. Our community of practice (Wenger, 1998) enabled us as knowledge workers to develop our own small system, in context, with open invitations and shared leadership. Then management stepped in. Seeing our identity and gatherings as ideal sites for doing thinking on their behalf, they asked us to take up issues related to product positioning and customer satisfaction. I still believe they were jealous. What originally emerged as an organic and loosely coupled network was co-opted into being an artifact useful for serving managerial goals. The community of practice did not survive. Had leadership for creativity in a contemporary, complex context been in play at the organisational level, as it was at our micro level, I can imagine an outcome of expansion and adaptation instead of extinction.

Within the larger organisation, our community represents a Complex Adaptive System (CAS) that is characterised as a dynamic system formed of interactive agents engaged in cooperative behaviours (Uhl-Bien, Marion, & McKelvey, 2007). Demonstrating an emergent quality, Complex Adaptive Systems at the macro or organisational level involve multiples of systems that influence each other, self-organise into new systems, and arise through interaction (Stacey, 1995). At a micro level, small changes can become amplified into changes that show up somewhere else in the system (Stacey, 1996a). Analogously, a flock of birds forming a flying pattern as they soar and re-forming as they merge with another flock can represent a CAS. What appears to be chaos resolves into a dynamic shape. There is an underlying order, but it is not rigid. There are common patterns of interaction, but they are not dictated by a hierarchy. There is a process of leadership, but it may not reside in formal titles or be carried out by the same agents in the same way day after day. "Neither stability nor chaos is capable of exhibiting the characteristics of complex systems – such behavior can only exist balanced at the edge of chaos" (Boal & Schultz, 2007, p. 428).

As Wheatley (1999) notes, if creativity in organisations matters, and organisations are more correctly characterised as "living systems, possessing the same capacity to adapt and grow that is common to all life" (p. 15), then what is leadership for creativity in complex organisational systems? In a related question, if patterns of

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interaction between people are part of organisational life and are emergent, self-creating and self-organising, full of complex responsive processes (Stacey, 2012), is there a role for leadership when change and creativity arise in small interactions?

What follows is a brief discussion of the intersection of creativity and learning in organisations, the focus of leadership for creativity, and individual attributes that appear critical for these leaders. To provide contrast, several leadership theories will be discussed in relation to the order-chaos continuum and will be followed by a conclusion utilising a comparison of two paradigms of leadership: leadership in the industrial age versus leadership in the knowledge era.

THE INTERSECTION OF CREATIVITY AND LEARNING IN COMPLEX ORGANISATIONS

From the perspective of complexity, when a shadow system, an informal self-organised, interacting set of agents emerges, it can push up against the formal, control-oriented system as depicted by organisational charts. In the interaction between the emergent and the enfranchised lies the possibility of creativity. "[T]he formal systems operate in a stable way…while the informal system operates in a destabilizing manner to promote change" (Stacey, 1995, p. 485). Neither chaos nor complete order are generative in the way that the edge between them is.

In the example I used above, the group of colleagues was the shadow system and upper management was the formal system. Order, through the use of normal managerial controls like scheduling or budgeting, is the bailiwick of the formal system. Order is important. The shadow system eludes the effort to maintain order like water that finds its way to the river and arises as interests intersect. If the informal system did not have a formal system to react to, organisational life would be chaotic. When order and chaos meet, change and adaptation, creativity, innovation, and learning can occur.

In this simple story lie several sites of creativity (Watson, 2007). Creativity players can be agents, such as individuals or teams, influencing each other, introducing unexpected factors, and stimulating novel responses with "interactions between agents within and across system boundaries, who are together creating and recreating their environment" (Stacey, 1995, p. 484). Creativity can be the impact that shadow systems have on order, stimulating an organisation into adaptation. From these examples, it is evident that creativity in organisations can occur at different contact points of systems and be found in individuals, teams, or organisations. Development of novel responses and adaptation are examples of learning and also of creativity. If learning is occurring, there is a good chance that creativity is as well. If learning by people, teams, and organisations is suppressed, so is creativity.

A stimulus for learning is disorder. "The things we fear most in organizations – disruptions, confusion, chaos – need not be interpreted [in a negative light]. Instead, these conditions are necessary to awaken creativity" (Wheatley, 1999, p. 21). Disorientation can play a profound role in learning. We can take the disequilibrium that comes from one system affecting another and consider it as a normal and productive phenomenon of organisational life.

One way people learn and go through significant reshaping of their fundamental views is through a transformational learning process (Mezirow & Associates, 2000). It is precisely the disequilibrium we experience that calls into question our existing narrative about ourselves and the world around us. Being fired, getting divorced, losing a home to fire, being catapulted into public life, or travelling in far-flung culturally unfamiliar lands can be experienced as disorienting dilemmas. From a complexity perspective, these individual disruptions could be called an edge of chaos. When a need for reconsideration of how things really are becomes the challenge, we can work through a cycle and develop foundationally new meanings. We can engage in reflection, dialogue, exploration of new roles, building confidence in new roles, or understandings and reintegration of new perspectives or habits of mind (Mezirow & Associates, 2000).

The experience of transformational learning is not necessarily sought out. Contexts and current events can arise that call on the need for self-reflection and critical questioning. It is the response to disequilibrium that can lead to a learning outcome or to the contrary—an internal psychological stalemate. The challenge is met with emergent new perspectives or it is not, and the opportunity for self-creativity passes.

Being capable as a transformational learner means having a capability to tolerate the edge between competing views, even irreconcilable views. A recent example is a judge who was bound to uphold sentencing guidelines with which he did not agree. Partly at his instigation, a legal technicality was used to overturn the defendant's sentence. Paradoxically, upholding his sense of justice meant watching his judgment be dismantled. This matters because "…individual minds are creative…when they can hold paradox in the mind" (Stacey, 1996a, p. 115).

Gaining new perspectives and/or gaining new meaning schemes illustrate a link between learning and creativity particularly in the face of disruption, but there is another process that reveals it from a developmental stance. Constructive developmental theory takes the position that "facing complexity requires a more complex way to understand oneself and the world" (Harris & Kuhnert, 2007, p. 48). Movement from one's current developmental level to the next is stimulated when confronted with limitations in one's way of understanding. Extending this theory to the domain of leadership, developmental levels have been described that characterise the growth of views as a leader moves up the levels (Harris & Kuhnert, 2007; Strang & Kuhnert, 2009). At low levels, leaders are rule-bound, focused singly on their own needs, and not able to evaluate other opinions against their own. Their primary frame of reference is their own personal agendas that they believe to be true for others as well. Experiences and events are considered in relation to whether or not the leader's goals are being met. Through experience, learning and growth, leaders at a higher developmental level can see variations in situations and can defer pursuit of their own goals but are deeply concerned with how they are viewed by others.

Even more developmentally advanced leaders can utilise information as a factor that may outweigh consideration of how they are viewed. They are therefore more capable of reaching independent judgment and decisions. Greater ability to see how others are bounded by rules and what their perspectives are enables these leaders to take more elements into account and see greater complexity. They are willing to risk harmonious relationships because, unlike lower level leaders, they are willing to overlook the needs of self and others.

At the highest level, leaders can observe concurrently both a situation and themselves. They can see their own value system and can operate from a value system focused on the needs of much larger entities than themselves, such as organisations. They see the importance of other paradigms besides their own and are able to tolerate unresolved paradox. In complex organisations, these developmentally more advanced leaders will likely be less personally torn apart by the edge of chaos.

It is a point of some interest to take this intersection of creativity and learning in complex organisations and consider the implications for leadership at the edge of chaos, a fertile ground for creativity. An individual's capacity to use disequilibrium as a stimulus for transformational learning and developmental growth is the story from the human growth and development perspective. From the leadership perspective, being more fluent in learning and more able to tolerate, indeed embrace, irreconcilable views become part of what leadership needs to influence in others.

THE FOCUS OF LEADERSHIP FOR CREATIVITY

Complexity theory, as applied to organisations, decentres conventional managerial practices such as strategic planning because even with careful and thorough selection procedures, quality decision making and governance, long-term outcomes are not always predictable (Stacey, 1995).

In a CAS, leadership is less reliant on formal authority structures because informal systems interact without the need for, or in spite of, official lines of communication. Leaders may not be aware that they are leaders or may serve in that role in a shared capacity (Schneider & Somers, 2006). Leaders shape the context, recognise recurrent patterns of interaction among sub-systems, and serve as catalysts (Boal & Schultz, 2007). They also engage in everyday, practical behaviours like designing routines and processes, interpreting, and influencing groups (Stacey, 2012).

In complex organisations, particularly at the edge of chaos, leadership can be about fostering learning, encouraging adaptability, developing a way to view instability, and resisting the comfort of operating in a common, reinforcing organisational pattern or culture. Anticipating that a ripple can spread unpredictably, leaders can introduce simple rules and contacts between subsystems. They can encourage development of themselves and others such that there is a willingness to engage in challenge and change. They can help prepare others to function as leaders capable of stepping in when roles shift and there is a need for independent thought and innovative behaviour.

ATTRIBUTES OF LEADERS FOR CREATIVITY

Non-mechanistic and adaptable are two of the characteristics of leaders in a CAS. The system itself is engaged in adaptation and learning, so those who seek to support and stimulate creativity must not work to compel order or suppress interaction. Formulating extensive perspective shifts within his or her own understanding of an organisation and how it works, the leader needs to be capable of deep, transformative learning. Tolerant of ambiguity, and even embracing paradox, a leader needs to be on an upward developmental trajectory. The leader needs to be capable of communicating in the small interactions through which patterns emerge while at the same time, grasping the large and seeing as much of the system as an individual can. Willing to cede a command and control role, the leader should recognise that it is possible to influence the system through planting creative ideas that may take on a life of their own. Finally, fostering learning and development in others, a leader needs to be immune to the disease of dogmatic thinking and be willing to encourage wariness toward it in others.

A few of these attributes require leaders to engage in personal learning that challenges taken-for-granted assumptions. Where managers who conduct their functions in the interest of greater order may never have to uproot and replant their foundational understanding of how their work impedes or affects change, leaders for creativity need to be able to engage in this form of agriculture regularly. The experience of transformational learning cultivates critical self-reflection skills (Mezirow & Associates, 2000). Being disoriented because of dawning awareness that one's efforts as a leader are ignored, not because of followers' sloth but because of having chosen a poorly conceived project, could be grounds for a transformative reframing. When the seeds of reflexive inquiry are sown, they can bear many generations of fruit and can be self-seeding.

"*Reframing* [italics in original] requires…the ability to break frames" (Bolman & Deal, 2008, p. 12). Being fluid in reframing is more than useful; it is a form of cognitive flexibility that enables creative leaders to reimagine how their organisation actually works and what its identity is. It will not be enough for leaders in a CAS to accept a new dictum that systems evolve unpredictably and leave it at that. Leaders who intend to influence for creativity will be observers (Stacey, 2012) of how various systems are interacting and will communicate meanings they continuously formulate (Boal & Schultz, 2007).

It is not only deep questioning and reframing that describe the unusual demands placed on creative leaders. It is the capacity to see more than one frame (or mental model) at once and the alacrity to move among them. For example, a leader who of necessity engages in political behaviour to put initiatives into motion will recognise the jungle where he or she resides; then when observing how administrative processes are functioning, he or she will shift to using a frame that has a focus on structure (Bolman & Deal, 2008). Becoming too attached to and influenced by any one frame is more than simply being narrow or shallow. It is dangerous to leadership for creativity. A prime example is the factory frame or metaphor. Operating each day as if efficiency is optimised by controlling and fixing flows of information between departments in standardised ways, like the famed TPS report in the movie *Office Space*, has the potential to lead to excessive formalisation. According to Boal & Schultz (2007),"[T]he inertia of Weberian-style bureaucracy" (p. 428) is a feature of the desire for order when framing organisations in the machine metaphor. Far from influencing toward the edge of chaos, this frame encourages the use of instruments for control, not encouragement for creativity.

No matter which frame is selected, one of them is likely to be the lens through which a leader looks at organisations. Even with good vision, we all have on a pair of glasses at any given time. We conduct our daily work lives on the basis of our underlying understanding of how things really get done in our organisations. It is unconscious and pernicious. Unchallenged, these understandings can lead to dogmatic positions. Consider the difference between a leader who nimbly reframes perspectives and helps others to do the same and one who doggedly refuses to accept alternative explanations and thereby discourages the creatively inclined.

Being able to see more than one frame or paradigm at the same time is a capability held by leaders at more advanced developmental levels (Harris & Kuhnert, 2007). The particular benefit of this attribute for creative leaders is that they can help their organisations live at the border between order and chaos which is where a CAS emerges. When they see storm troopers for order attempting to draw the organisation into a machine-like structure or, on the other hand, anarchists undoing or resisting promising decisions, creative leaders will be capable of seeing the competing perspectives.

THE CHAOS/ORDER CONTINUUM AND LEADERSHIP THEORY

With chaos at one extreme and order at the opposite, the creative space is where they meet: sufficient order to keep the paychecks coming and the raw materials on hand, sufficient chaos to be able to group and regroup as temporary departments to solve different problems. Considering the intersection of creativity and learning along with a view of organisations as adaptive, complex systems and the attributes of leaders for creativity, are we served by traditional modes of leadership? Or stated in a more challenging tone, "[W]hen you cling with so much determination to control, are you destroying the capacity of your organization for complex learning?" (Stacey, 1996b, p. 10).

While it is easier to see the detrimental impact of leadership that is overly controlling, the opposite side of the continuum poses problems for leadership aimed at creativity. Take the idea of laissez-faire leadership, that is leadership in name only (Bass & Avolio, 1994). It entails no effort to encourage growth or increase motivation among followers, no plans, slow decisions, and avoidance of obligations. A leader in this role does not offer enough of a context or challenge to stimulate the messy edge that abuts order. There is no shaping of the environment to put subsystems into contact with each other or desire to put an initiative into action knowing that the consequences could play out in interesting ways. There is no favorable draw toward creativity or learning, and there is no leaning toward change. An employee in such an organisation could experience quite a bit of freedom but could also become frustrated knowing that nothing will have changed by the end of this year or the next. Faulty administrative processes will still cause misunderstandings and delays. Enthusiasm will be met with failure to follow through.

As in the story about finding the right temperature, laissez-faire leadership is like the porridge that is too cold. Too hot is the other extreme, authoritarian, mechanistic, and controlling.

Management by exception is all about looking for deviation from correct behaviours, identifying mistakes, and supplying corrections (Bass & Avolio, 1994). Considered to be within the transactional type of leadership, management by exception relies on an exchange relationship between leader and follower. The follower carries out instructions or duties because doing them is participation in a mutual exchange. Leader advises follower of mistakes made, and follower amends actions, gets to keep job and paycheck; leader is rewarded with accomplishment of tasks. An organisation that values such leaders will have structures and standard operating procedures intended to optimise the performance of all involved. Rule-governed and defensive, players in this game want to avoid the omnipresent possibility of criticism. Creativity, learning, and change do not have game pieces on this playing board.

Closer to the medium temperature porridge, but still too hot, is transformational leadership (Bass & Avolio, 1994). While known for being associated with change, transformational leadership is a top-down approach that is not a fit with the leader role in a CAS. When the system is self-organising and emergent, with leaders providing stimulus and rotating into and out of the role, a transformational leader's provision of unity of vision and efforts to coalesce the organisation around a common culture is too much order. The transformational leader also uses his or her idealised influence to bolster the hearts of followers through trust in a strong role model. Placing the leader on this pinnacle means that followers look up instead of around at themselves. Organisational plans, as expressed through inspiring messages, are crafted and disseminated through established channels and reinforced through symbols and stories. Making sense of history through the telling of tales is also a role a leader in a CAS should play, but it is not with the intention of providing direction. It is to promote dialogue so that perspectives are formed and shared (Boal & Schultz, 2007).

The transformational leader wants to encourage and harness innovative behaviours, creativity, and learning in the interest of pulling together toward the imagined goal. Except for intellectual stimulation, there is no implicit match between the characteristics of a transformational leader and the attributes that appear important for creative leadership in a CAS. In transformational leadership theory, the leader opens employees' minds to new ideas and challenges them to try out new perspectives. The leader may also encourage followers to develop themselves through individualised consideration.

Adaptive leadership (Heifetz, 1994) is a process, not a set of behaviours found in a leader person. In the chaos/order porridge metaphor, it is just about right. “Adaptive leadership is an emergent, interactive dynamic that produces adaptive outcomes in a social system” (Uhl-Bien et al., 2007, p. 306). It is what enables adaptive work, which is characterised as that which calls on learning in order to address conflict, particularly contradictions in one’s own value system. The contradictions are the source for the desire to see new ways of getting things done. This is reminiscent of transformational learning and its disorienting dilemmas, as well as constructive-developmental theory’s recognition that we grow because we aren’t served by our current understandings.

Adaptive leadership is practiced by those who have authority and those who do not. It is the use of authority that differs so strongly from the command and control modes of leadership. Instead of influencing through transactional exchanges, leaders use influence to identify and frame problems and steer resources to those engaged in designing solutions. The concept of adaptive leadership includes recognition that leadership emerges in different collaborative efforts and that it can be shared. Attributes for those in authority include having flexibility of the mind to recognise emergent problems, being able to see interdependencies, and encouraging contrary views.

Creativity and learning are what adaptive leadership uses, needs, and encourages. “Because making progress on adaptive problems requires learning, the task of leadership consists of choreographing and directing learning processes… [It] often demands changes in people’s attitudes and behaviours” (Heifetz, 1994, p. 187).

Rather than being a product of model development, with a built-in intention of describing a particular type of leadership, the concept of adaptive leadership considers the daily life of organisations that contains a wide range of action—creativity, change, conflict, and resistance.

The idea of a CAS poses a challenge to traditional models of leader behaviour, leader attributes, and the nature of leadership itself. Like the edge of chaos, leadership for creativity is found in the adaptive space toward the middle of the chaos/order continuum.

DECONSTRUCTING CLICHÉS

This idea of an organisation as a more organic, complex system, capable of changing, relying on interaction between subsystems, reacting to the introduction of new factors in surprising ways and self-organising, is a change from the simple systems view that has been the prevailing discourse about organisations. Nudging the old metaphor of simple systems aside helps us to question and reframe our understanding of how organisations function.

Taylorism and the rise of Scientific Management brought the engineering model into the fore (Whitsett & Yorks, 1983). Through time and work studies, industrial engineers designed work to be carried out in the one best way. Taylor's work was reviled at its inception in the early 20th century as exploitation of workers, but its precepts of efficiency, management control of work, and removal of independent thinking by employees is the legacy we live with today. Reducing the size of workforce to reduce costs and maximise profits is a valued technique. It is accepted that strategic decision-making requires the wisdom of those in control. Even with more humane concepts of leadership, such as Transformational Leadership, the thinking still resides in the heads of the top leaders. It's fine for efforts at creativity and innovation to occur, and they can be encouraged; but ultimately, choices of which initiatives to emphasise are made by leaders.

The counterargument that complexity theory proposes is instead of simplifying, "organizations must increase their complexity to the level of the environment rather than trying to simplify and rationalize their structures" (Uhl-Bien et al., 2007, p. 301). Not only should we critique the industrial age ideas about size, structure, management, leadership and labor, we should contemplate the opposite.

In the knowledge era, learning is the new form of labor (Elkjaer, 1995). For example, it is expected that knowledge workers gain sufficient mastery of word processing to be able to produce our work. We have to be adept at learning. Returning something as simple as responsibility for learning to us, returns us to agency. And agency is what happens in a Complex Adaptive System.

The industrial era form is not the one best way. There is no one best way. We can't formally design a CAS; but as leaders for creativity, we can influence the context, encourage the dialogue, critique our own frame of reference, engage in deep learning and look for conflict.

The old saw that organisations don't change may well be true, for some. Those organisations become less and less viable and relevant. Overly rigid systems have a tough time overcoming the status quo and bureaucratic enforcers. Adaptability and responsiveness within an organisation, however, have the potential to improve an organisation's capacity to work with complex external forces, such as globalisation and economic uncertainty. Change and creativity are not unnatural.

Finally, creativity and leadership are not the province of the few. As agents in organisations, we learn in complex ways, and we influence others. We take in new information, reframe our perspectives, draw from practical experience, observe and interpret events, and develop. In other words, we engage in creativity. We affect others' views and are affected by theirs, our group interacts with another work group. If not suppressed, our combined work will be generative. We will have engaged in leadership for creativity.

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MARNA HAUK

COMPLEX REGENERATIVE CREATIVITY

> If the transition is to be made—if the world is to make the change from the degenerative to the *regenerative* and thus sustainable mode—then priorities must change….With more interactions involved, more options available, and far more flexible technologies to deal with, regenerative design provides virtually unlimited opportunities for *invention* and for *devising varied ways of combining elements.* In such situations, analysis and deterministic methods usually provide knowledge of parts and mechanisms, but they rarely yield adequate answers. *Creativity enters the process in the key role of assembling diverse parts, often in unexpected ways.* Regenerative design involves both art and science not separately but merging together.
>
> – J. T. Lyle (1994, pp. 37–38, 45) *(emphasis added)*

Positioned at the vital intersection of chaos, systems thinking, fractals, creativity, and regeneration, this research theorises complex, regenerative creativity. Tracking the thinking of twenty creativity and chaos scholars, it traces parallels between the dynamics of the creative process and the conditions for chaotic emergence. Creative emergence and earth regeneration are both autopoietic. Connection with the regenerating patterns of living planetary systems can serve as a strange attractor for complex creativity. Process-patterns from nature and bioculture catalyse regenerative creativity and result in ethical and educative engagement and innovation, the enhancement of life-giving diversity, and the reduction of dogmatism. In particular, the transdisciplinary quality of ecofractal-activated regenerative creativity is consonant with the terrain of sustainability challenges. During this daunting epoch of the Anthropocene, complex regenerative creativity offers to crystallise the deep paradigm shifts required for planetary and local flourishing.

Spider Woman, a Navajo world-maker, spun the web of creation across the canyon-top lands. The drops of falling rain landing on the web made rainbows. These rainbows on the web drops sparked the imagination of five-fingered people (personal communication, John and Lupita McClanahan, Diné, September 9, 2011). Connection, creation, and creativity weave together. This research theorises a regenerative, complex creativity, positioned at the vital intersection of systems thinking, creativity, nature, and bioculture. The chapter traces parallels between chaotic and complex systems emergence and creative processes, particularly when catalysed by engagements with nature and bioculture. This inquiry articulates how

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 97–121.

complex creativity catalysed by process-patterns from nature and bioculture results in ethical and regenerative engagement and innovation.

THE SIGNIFICANCE OF REGENERATIVE COMPLEX CREATIVITY

We are offered increasing opportunities to deepen in our understanding and change our practices and systems to ones that sustain life. It becomes increasingly clear that the current, dominant systems of care and provisioning are harm-causing, insufficient, and unsustainable. Power consolidation, resource extraction, industry, and overconsumption have produced inequity, pollution, structural violence, species extinction, and planet-scale systems disturbance. Scholars currently describe the level of human impact as massive and planetary, hastening the era of the Anthropocene (Crutzen, 2006). Turbulence, extinction, and climate change from harming feedback loops point to the increasing attacks on the integrity of the fabric of planetary life. Superficial green-washing of industrial production threatens to distract us from effective, system-level innovations (Goleman, 2009) and the cultivation of ecological intelligence (Bowers, 2012).

Sustainability as a field engages in the triple considerations of equity, economics, and ecology to establish integrated approaches to these planetary challenges. It embodies "the urgent need for change from unsustainable practices towards advancing quality of life, equity, solidarity, and environmental sustainability" (UN Economic Commission for Europe, 2011, p. 7). Sustainability education (and education for sustainable development) explores how education can generate more sustainable and just economic and ecological systems, provoking "seismic" cultural shifts in paradigm, supporting "the necessity and possibility of a deep change in shared worldview if we are to manifest the transition towards a more liveable and sustainable world whilst workable options remain" (S. Sterling, 2009, p. 63).

Internationally recognised competences for educators in sustainability education offer holistic approaches that envision change to achieve transformation (UN Economic Commission for Europe, 2011). These competences include: (a) understanding systems thinking and the interdependent nature of relationships with generations, class, and nature while (b) emphasising problem setting, visioning, and creative thinking. The articulation of key sustainability literacies confirms the importance of (a) systems thinking and interdependence and (b) experiencing nature as model and teacher, including the ethnosciences (Nolet, 2009). This framework is consonant with the insights of many living wisdom traditions that connect creativity with ecological intelligence, biophilic affiliation, and traditional cultural knowledge, empowering a revitalisation of the local cultural commons (e.g., Bowers, 2012). Thus, during this daunting epoch of the Anthropocene, regenerative complex creativity offers to crystallise the deep paradigm shifts required for planetary and local flourishing.

Meanwhile, complexity, chaos, and creativity inspired by natural patterns are sourcing system-level innovation in an increasing number of arenas, including biomimetic invention (Bar-Cohen, 2006, 2012; Benyus, 2002), resilient social-ecological governance (e.g. Berkes, Colding, and Folke, 2003; Waltner-Towes, Kay, and Lister, 2008), ecological design (e.g., Van Der Ryn & Cowan, 1996, 2007), regenerative design (e.g., Lyle, 1994), ecological integrity and collaborative transformation (Manuel-Navarrete, Kay, & Dolderman, 2004), living buildings, biophilic design, and architectures of renewal (e.g. Cumberlidge & Musgrave, 2007; Kellert, 2005; Murphy, 2011), and living systems education (e.g., Ambrose, 2009; Bache, 2008; Cohen, Manion, & Morrison, 2011; Davis & Sumara, 2006; Doll, Fleener, Trueit, & St. Julien, 2005; Mason, 2008; Widhalm, 2011). Other cultural forces also affirm the need for attending to complex creativity: technological amplification requires radically adaptive modes of creativity (Thomas & Brown, 2011) and increasing organisational and problem complexity requires greater creative capacities (Maubossin, 2011). Richards (2001b) emphasised, “Clearly, this is an important time for creativity” (p. 249).

To respond to this timely opportunity, I articulate a theoretical framework for how creativity, complexity, chaos, and regeneration are connected concerns. Creativity has chaotic properties and exhibits qualities of complex adaptive systems. The complex quality of autopoiesis, the ability to perpetuate self-arising/self-organising systems, can guide us to develop self-organising (autopoietic) creativity in education and design. Sustaining creativity has regenerative and ethical effects across domains. Patterns from nature and patterns from human-nature collaborations (bioculture) cross scales, in fractal and chaotic ways, and spark creativity in small groups to infuse design practices with regenerative results. Regenerative creativity sparked by ecological and biocultural fractals liberates genius and encourages and harvests divergence, diversity, and ethics (see Figure 1).

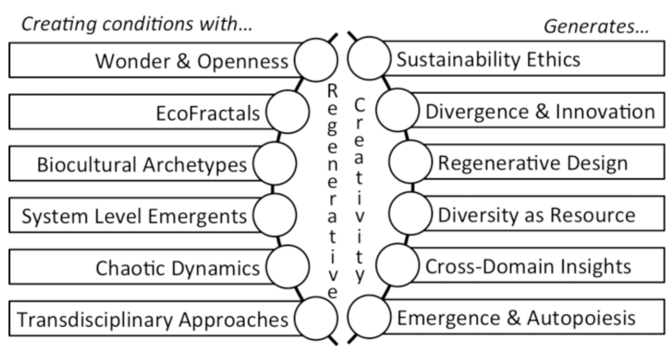

Figure 1. Conditions and qualities of regenerative creativity.

CREATIVITY, COMPLEXITY, CHAOS, AND REGENERATION

Creativity and chaos and complexity theory have long been linked. Educators, linguists, and researchers in multiple disciplines have identified this link (Fauconnier

& Turner, 2002; Taylor, 2011). Complexity-inspired research has sometimes been framed as *emergent participative exploration* (Christensen, 2005), *complex responsive processes perspective* (Stacey & Griffin, 2005), and *conceptual blending* (Fauconnier & Turner, 2002).

Complexity and regeneration are also connected. Autopoiesis, literally self-making (Capra, 1996, p. 97), is a concept from complexity science that marks the emergence of self-organisation for a system, particularly a living system. Capra's survey across the development of complexity science formulations identified several specific factors involved in complexity including: (a) the emergence of novel structures and behaviour modes that represent *new patterns of order* (b) within open systems operating in far from equilibrium states; with (c) a constant flow of energy and matter through them; (d) with system components connected in nonlinear ways; (e) resulting in amplifying feedback loops playing a central role; and (f) can best be described mathematically by nonlinear equations. He noted Eigen's hypercycles self-replication and Maturana's insight that these generate a network or web pattern of networks embedded in networks with a focus on the relationships and processes between components in which "the entire network continually 'makes itself'… produced by its components and in turn producing those components" (p. 98).

Capra (1996) described how the Gaia theory highlights this self-regenerating process via "a complex network of feedback loops that…bring about the self-regulation of the planetary system" such that, without teleology, life emerges and self-regulates (p. 104, 107). He noted that the emergent property of planetary temperature regulation arises consequent to the feedback loops between organisms and environment, not via any purposeful action. Margulis confirmed this planetary self-organisation phenomenon: life making, forming, and changing the environment within which it adapts (2004). As living systems are continuously regenerating and evolving, autopoietic complexity and regenerativity are related if not multivalently co-implicated across scale.

One could see creativity as a type of complex, regenerative process; in fact A. Sterling (2003) outlined exactly this parallel (see Figure 2) and noted that chaos theory and complex, dynamic nonlinear systems can unify the mechanistic and organismic views of creativity. In chaos theory, the farther a system from equilibrium, the more sensitive it is to slight changes in initial conditions, which is called sensitive dependence on initial conditions (SDIC).

A. Sterling found the question of setting initial conditions less interesting than understanding internal and external constraints on chaotic dynamics in creativity. In particular, she drew parallels with the traits characteristic of creative individuals—including those evidenced in the creativity research literature such as preferring nothing pre-structured, seeking out ambiguous situations, big-picture conceptualisation, flexibility, unconventionality, openness to experience, spontaneity, and overexcitability—and the chaotic dynamics of movement away from equilibrium.

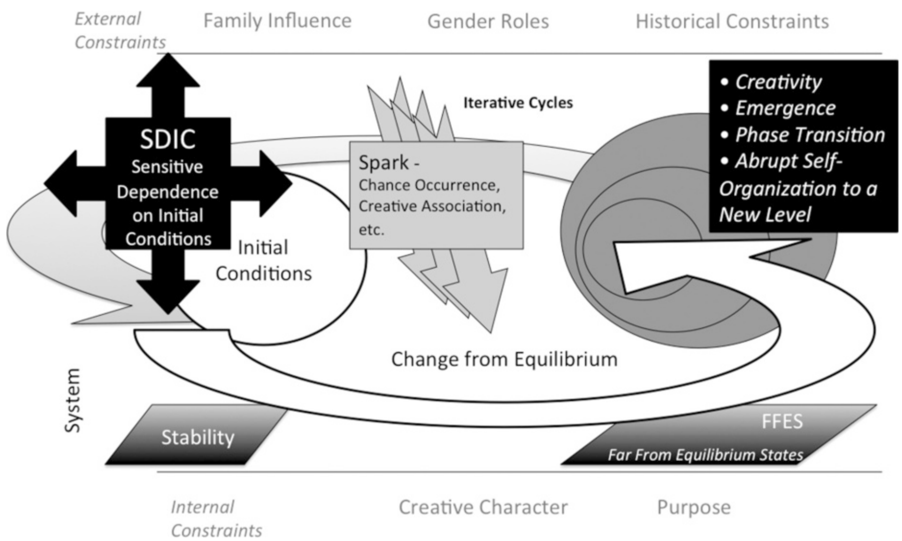

Figure 2. Human creativity and chaotic dynamics: Visualising A. Sterling's (2003) model.

The chaotic dynamics of creativity extend to amplification and feedback. A. Sterling (2003) insightfully suggested that "imaginational over-excitability…. may be an internal constraint that persistently pushes or entices individuals into far-from-equilibrium states" (pp. 163-164). Ambrose (2009) characterised this offbeat quality of high creatives as "a fruitful asynchrony of… those who don't quite fit in…[who] establish an uncomfortable but productive dynamic tension" (p. 71). A. Sterling found the purposefulness that leads to creative productivity described in the literature as possibly serving as "an 'initial condition' that encourages the human system towards a far-from-equilibrium state, thus priming it for a creative leap" (p. 165). She explored Gruber's concept that deviation-amplifying systems are necessary for creative work and that they support exploring and elaborating fledgling discrepancies or innovations. Deviation amplification represents an echo of Capra's inclusion of amplifying feedback loops as one of six characteristics of complexity. Researchers (Richards, 2001b; A. Sterling, 2003) have noted the important parallels between Csikzentmihalyi's work on flow and chaotic dynamics, including how challenging goals and burning questions can drive and amplify creative processes and how total concentration and joy are generative.

Chance and serendipity also play a role in creativity, much as seemingly random instigating perturbations in complex systems can cause generative self-organisation, also known as autopoiesis. There is a difference between sparking and sustaining creativity and complex systems. Regenerative systems are self-sustaining, just as autopoietic (generative) complex systems are self-sustaining as described by A. Sterling (2003):

> A system driven far-from-equilibrium by a variety of constraints is invaded by fluctuations caused by some factor that becomes amplified by the nonlinear dynamics, and the whole system spontaneously and abruptly reorganizes to a new level of organization…. [N]onlinear dynamics also can give rise to sustained processes. The new level at which a system arrives through self-organization may represent a new equilibrium. (p. 173)

In this way, regenerative creativity represents a systems-level, sustained gyre of innovation.

Other creativity and innovation scholars confirm the connection between generativity, creativity, complexity, and sustaining gyres of innovation. The conditions that spark regenerative creativity are *cultures* of innovation. Barron (1995) emphasised a complexity and systems approach to the ecology of creativity, which he considers emergent. Goldstein, Hazy, and Lichtenstein (2010) named these "ecologies of innovation," a "system-wide set of processes and interactions" that are characterized by systems of difference, adaptability, interaction resonance (feedback amplification), and using cooperative strategies and symbiosis (pp. 27-33). Wood (2013) advocated meta-design for creatives to realise *synergies of synergies* in ecomimetic sustainability design systems. Csikszentmihalyi's (1999) multiscale systems perspective of creativity noticed that support and understanding of the cultural domain and contexting field are required to nurture and proliferate individual creativity and give it meaning and persistence. Sawyer's (2010) research with improvisational groups generates insights into another complexity-informed theory regarding creativity beyond the individual, theorised as collaborative emergence. Collaborative emergence focuses on improvisation and action in group creative productivity, noticing the parallels between complex emergence and collaborative creativity. Another creativity researcher noticing correspondence between emergence and creativity cultures, Runco (2007) described nonlinear cascades of inventions that lead to subsequent inventions as creative emergence via trigger effects (from Burke) and *emergenesis.* The trigger effects Runco mentioned find a clear parallel with chaos's perturbations in contexts of sensitive dependence on initial conditions. These level-hopping, chaotic emergence cultures of creativity, including ecologies of innovation, domain and field feedback, collaborative emergence, and emergenesis, all indicate polyscale interactions for creativity and begin to describe the rich, emergent *edge of chaos* at which creativity can be continuously self-emerging, replenishing, and regenerative.

The intersection of chaos dynamics and creativity also drives Richards' explorations of fractal creativity. Richards (2001b) has explored the connections between chaos theory and creativity in depth via the Guilford Intellect Model for divergence and convergence. Richards' work focuses on the strange attractors of creativity that can either entrap or liberate and on exploration of individual as well as group-level effects. Richards applies the concept of strange attractors that in chaos indicate "an infinitely complex pattern in phase space that never exactly repeats" as existing in cognition and creativity as "a mind screen of complex and interconnected pattern recognition devices" (p. 251). Richards finds that these meta-patterns can liberate with their infinite possibilities or overly constrict, as suggested by Schuldberg if they become bound to a limited-cycle or point attractors, what Goertzel (1995) identified as the chaotic strange attractors of belief systems.

These unfavorable but self-reinforcing habits of thought parallel system traps in, for example, the complex adaptive systems of ecosystems. System resilience (chaotic momentum) actually reinforces undesirable regimes (Gunderson, Allen, & Holling, 2010). Dogmatism is an example of this creativity-killing type of limited strange attractor of thought. Dogmatic insularity can "severly suppress, warp, or even destroy the development of creative intelligence" (Ambrose, 2012, p. 64). The regenerative design and ethics section at the end of this chapter further explores the possible relationships between ethical characteristics of regenerative complex creativity, which is the flip outcome from degenerative cycling of dogmatic point-attractors of thought.

Richards further noticed the fractal nature of memory paralleling Guilford's creative products treatment. Richards does note the parallel between novel creative insight, what A. Sterling refers to as hyperexcitability and the hypersensitivity of chaotic and complex systems. Richards (2001b) compellingly emphasised the process-nature of the chaotic patterns of divergent thinking. Capra (1996) articulated that the flow-through rather than the abstracted shape of the attractors and patterns is the important focus. Richards (2001b) calls these traits rather than states (2001b); Schuldberg described them as paths not outcomes (2007). Chaos mathematician Fleener focused on function, interactive pattern, and self-emergent structures rather than mechanistic relations (2002). This can be a difficult perspective for our shape-bound, morphological, scientifically trained cognition. Richards (2001b) applauded Guilford's systems and transformations within his taxonomy of products as emphasising dynamic evolution and movement:

> It is best, perhaps, to imagine these creative outcomes shimmering and transforming continuously in phase space—indeed, with each new thought or look we take….[A]ttractors lyleare dynamic…figures…constantly shimmering and twinkling in their areas of high activity and chaotic collapse, perhaps like stars seen through the atmosphere. Here is the constant ongoing arrival of creative insights, big and little, as the entirety accommodates to the arrival of each new part and reconfigures itself accordingly. Here are the bifurcating births of new possibilities that diverge from the context that spawned them and may take the configuration in new directions. (p. 254)

Inspired by this sparkling and dynamic complex creativity, Richards advocated for "living on the edge of chaos" in our creative lives as a way to position ourselves near dynamic, self-perpetuating patterns of sometimes disruptive, possibly eruptive change (p. 258). She further proposed creating learning cultures that "turn the heat up" on supporting positive divergence, an openness to nurturing eccentricity so we do not miss the opportunity to collectively catalyse a shift (p. 259). Ambrose (2009) affirmed that individuals and cultures evolve and strengthen at this complex evolutionary edge of chaos. He suggested that chaotic order can provide the context for developing into higher levels of organisation, cultivating optimised balances of self-actualisation and cultural evolution while avoiding entrapment of fixity and culture-locking or excessive anarchic turbulence.

In sum, creativity exhibits nonlinear dynamics and chaotic, self-organising emergence. Table 1 synthesises both A. Sterling and Richards with twenty theorists to describe the "Parallels of Creativity and Chaotic Emergence." Open systems parallel wonder and an attitude of openness. Both external and internal constraints create the cauldron of context for the chaotic emergence of creativity. Habits of living on the edge of chaos generate far from equilibrium states. Imaginational overexcitability, spontaneity, serendipity, and novel assemblage correspond to sensitive dependence on initial conditions and can generate bifurcation points. Ongoing creative flow parallels flow-through for chaotic emergence. Habits of concentration, joy, and synergy offer amplifying feedback loops. Collaboration, novel associations, and transdisciplinary approaches create networks of networks and further reinforcing contexts. Culture gyres of innovation are sustained by regenerating autopoiesis. Patterns from nature and bioculture catalyse big picture emergence leading to gestaltic intuition.

Table 1. A Synthesis of Parallels – Creativity Phenomenon and Characteristics of Chaotic Emergence

Creativity Phenomenon (1,2,4, 5-22)	*Characteristics of Chaotic Emergence (1,2,3,9,10,17)*
Wonder, openness (1, 2); nurturing eccentricity (2); "diversity-positive"; positive divergence (4, 9); openness to experience (1, 2, 4, 10, 11, 12, 13, 14, 17)	Open Systems (1, 2, 3)
Imaginational overexcitability (1); spontaneity, serendipity (1, 2)	Sensitive dependence on initial conditions (SDIC) (1, 2, 3, 10, 17)
Age, culture, context – family influence, gender roles, historical context (1); domain and field contexts (11)	External constraints (1)
Creative character, purpose (1); e.g., prefer nothing pre-structured (2)	Internal constraints (1)
Living "on the edge of chaos" (2, 4, 10); hypersensitivity (1, 2); "fruitful asynchrony… of those who don't quite fit in" (4); openness to/seeking ambiguity (1, 2); live by improvisation and bricolage (10)	Far from equilibrium states (1, 2, 17)
Creative sparks, chance occurrence (1, 2, 10)	Bifurcation points (1, 2, 3, 9, 17)

(Continued)

Table 1. Continued

Creativity Phenomenon (1,2,4, 5-22)	*Characteristics of Chaotic Emergence (1,2,3,9,10,17)*
Patterns from nature (5, 6, 8, 9, among others); ecofractals (9); biocultural archetypes (9)	Bifurcation instigators; strange attractors; patterns; emergents (9)
Ongoing, creative flow (11, 1, 2); traits not states (2); paths not outcomes (10);	Emphasis on flow-through rather than shape or static structure/morphology (2, 3, 17)
Idea synergy, brainstorming, cooperation (1, 2); explore and elaborate fledgling discrepancies and innovations (2)	Amplifying feedback loops (1, 2, 3, 9); (e.g., hypercycles) (3)
Total concentration and joy (1); challenging goals and burning questions (1)	Amplifying feedback loops (1, 2, 3, 9)
Pattern recognition; big picture conceptualisation (4); holism, gestaltic intuition (6)	Emergence (3, 9, 17); strange attractors (1, 2, 9, 10); patterns, fractal patterns, patterns of order (1-9); system meshing (7); collective beings (20)
Collaboration, novel connections (1, 2); novel assemblage (7); creative association (1, 2); double scope blended networks (7); transdisciplinary approaches (1, 2, 3, 4, 6, 7, 8, 9, 13, 15, 16, 19, 20, 21)	Create networks, webs (3, 9); networks of networks (3, 9); emergent new multisystems (20); metaparadigm (21)
Systems-level sustaining gyre of innovation (this chapter, 9); creativity systems at the intersection of field, domain, and creator (11); creative collaborative emergence (12); cultural ecologies of innovation (13); a systems approach to an ecology of creativity (19); emergenesis catalysed by trigger effects (14); synergies of synergies (18); ecological intelligence (16); riding the storm toward connective cultural consciousness (15)	Autopoiesis (3, 17, 20); makes more of itself, sustains itself (2, 3); regenerates (8, 9); self-organisation (1-4, 7-10, 17); "reflecting their always original and self-renewing natures" (10)

Note. A synthesis of direct phrases and concepts from (1) A. Sterling (2003); (2) Richards (2001b); (3) Capra (1996, 2002); and (4) Ambrose (2009); with (5) Cobb (1977); (6) Mathews (2008); (7) Fauconnier & Turner (2002); (8) Lyle (1994); (9) Hauk (2007, 2011, 2013a, 2013b, 2013c); and including (10) Schuldberg, 2007; (11) Csikszentmihalyi (1990, 1999); (12) Sawyer (2010); (13) Goldstein, Hazy, & Lichtenstein (2010); (14) Runco (2007); (15) S. Sterling (2007); (16) Bowers (1995, 2006, 2012); (17) Fleener (2002); (18) Wood (2013); (19) Barron (1995); (20) Minati & Pessa (2006); (21) Montuori (2007); and (22) Craft (2010). Longer or more unusual phrases in quotation marks; almost all table material reflects direct quotations from sources as cited in the text of the paper.

DOMAIN SPECIFICITY, TRANSDISCIPLINARITY, AND COMPLEX REGENERATIVE CREATIVITY

Whereas some important creativity research focuses on domain-specific creativity (as discussed in Kaufman & Baer, 2005), other research supports the importance of inter- and transdisciplinary approaches to maximise creativity and cognitive diversity (see Ambrose & Cross, 2009; Kaufman & Baer, 2005). Regenerative creativity approaches creativity as a domain-general phenomenon and promotes inter- and transdisciplinary collaboration to increase cognitive diversity. Arguably, transdisciplinarity is key to productive, and we shall say regenerative creativity for big picture, regenerativity and sustainability issues. Some theorists warn against the risk of unintentional dogmatic traps of grand unifying theories and interdisciplinary team creativity (Baer, 2012, p. 166). One of the advantages of complexity-informed regenerating and regenerative creativity is a move away from "grand unifying theories" and towards richly textured and complex approaches that are in the process of ongoing self-replenishment. Pohl and Hadorn (2008) recommended transdisciplinary approaches to complex life-world problems, for example, in the environmental sciences.

Similar to the strengthening of ecosystems by biodiversity and the prevalence of complex intersections of high biological and cultural-linguistic diversities in global mega-diversity hot spots (Harmon & Maffi, 2002), regenerative creativity promotes innovative convergences of fruitful ecological and cultural pattern diversity "because the combination of remotely associated ideas can produce unpredictable, creative insights,...and the resulting idea mixtures produce better results in complex problem solving than would the collective contributions of homogenous groups" (Ambrose & Cross, 2009, p. 25). Complexity research demonstrates that increasing cognitive diversity enhances organisational vibrancy (Sargut & McGrath, 2011). Further, the emergent generativity and catalytic sustaining of complexity requires diversity and novel connections across domains. Moreno and Ruiz-Mirazo (2010) confirmed that open-ended growth of complexity in nature demonstrates resilience instead of fragility as a result of "new causal connections between domains that are not necessarily linked" (p. 74). One could argue that non-domain-specific (domain-general) creativity is a requisite for novel complexity; without this mechanism, complex systems would not be capable to carry out other transitions that involve a radically new way of organising their constituent and interactive processes (Moreno & Ruiz-Mirazo, 2010, p. 75).

Transdisciplinary contexts foster creativity for sustainability and regenerativity. Willetts and Mitchell (2007) found transdisciplinary approaches critical to the sustainability communities of practice. Krasny, Lundholm, and Plummer (2010) also found transdisciplinarity to be the most effective strategy at the creative intersection of complex resilience, learning, and environmental education. Regenerative design *requires* creativity to assemble diverse parts across social and natural contexts to produce innovation:

> If the transition is to be made--if the world is to make the change from the degenerative to the *regenerative* and thus sustainable mode--then priorities must change…With more interactions involved, more options available, and far more flexible technologies to deal with, regenerative design provides virtually unlimited opportunities for *invention* and for *devising varied ways of combining elements.* In such situations, analysis and deterministic methods usually provide knowledge of parts and mechanisms, but they rarely yield adequate answers. *Creativity enters the process in the key role of assembling diverse parts, often in unexpected ways.* (Lyle, 1994, pp. 37–38, 45, as quoted on the title page, emphasis added)

Lyle's insight that a holistic and flexible creativity can connect across silos and elements is compelling in its capacity to stop degenerative design and provoke a resurgence in regenerative designs.

Transdisciplinary creativity is also integral to sustainable solutions and regenerative design because it increases the diversity of learning communities and processes. Ambrose (2009) confirmed in particular that inter- and transdisciplinary creative groups produce more expansive divergence. Akkerman and Bakker's (2011) research on boundary objects and boundary crossing in educational contexts confirmed that the points of boundary (such as disciplinary boundary) crossing "are potential learning sources rather than barriers." Akkerman and Bakker also demonstrated that transdisciplinarity and domain-general creativity are critical for learning groups and communities of practice to remain dynamic, both in understanding the synthesis of decentred, multiple internal voices as well as in the dialogical multivoices and interactions of different minds expressing multiple meanings. Jackson (2003) has leveraged the metaphor of multiple, imbricated root mats growing and irrupting in polyvocal meaning with the term *rhizovocality* to express the possibilities of this rich interweaving, the diversity-as-resource approach to domain-general creativity and creative expression. Minati and Pessa (2006) emphasise complex and emergent systems must be designed to protect diversity and must consider diversity as a resource and not a problem, maintaining social multiplicity and the emergence of Collective Beings. Intersections of cultural practices open up *third spaces* that allow negotiation of meaning and hybridity (Akkerman and Bakker, p. 135); diversity is not just something to be managed, but something that incubates new learning and insight.

Minati and Pessa (2006) specified that, different from multi- or interdisciplinary approaches, "transdisciplinary approaches are taken when problems are considered between, across, and *beyond* disciplines, in a unitary view of knowledge" where the emphasis moves to the "dynamics between different levels of representation" (pp. 13-14). Minati and Pessa argued that transdisciplinary approaches are essential for complex phenomena in particular, for which classical mechanistic approaches are ineffective, and for which focusing on solutions for the problems rather than the people having the problems has only produced more difficult, new problems. By stressing that "the study of single, isolated components is ineffective and unsuitable for problems carrying the complexity of emergent systems and processes," Minati and Pessa underscored transdisciplinary approaches for complex challenges (pp. 14-15). Montuori confirmed that transdisciplinary approaches will produce creative, contextualising, and connective inquiry combining rigor and imagination (2005).

From a complexity and chaotic order perspective, we know that teachers are more like provocateurs than controllers. They take the role of creating conditions and providing instigations for creative complexity, potentially producing bifurcation points and contexts open to ambiguity (Briggs & Peat 1999; Davis & Sumara, 2006; Hauk, 2011). School leaders can support self-organising schools: "self-organization and renewal sustain reform and improvement in a school through relationships, communication, sense making, and dialogue and conversation" (Bower, 2008, p. 116). Effective teachers embrace complexity, value creativity and inquiry, explore, adapt, and synthesize, and "maintain an open mind to avoid dogmatic insularity" (Ambrose, 2005, p. 292).

In summary, complex contexts require transdisciplinary approaches. These transdisciplinary approaches cross scales, increase innovation, solve at the system level, and increase divergence. They increase, honor, and harvest the creativity and insights of diverse learners and communities of practice, and support regeneration and renewal rather than degeneration in design.

COMPLEX EMERGENCE AND REGENERATIVE CREATIVITY

Regenerative creativity catalyses complex emergence. Emergence blossoms in cascading and interdependent, trans-scale, fractal integrities in nature. W. Berry (1981) in *The Gift of Good Land*, noted in "Solving for Pattern" that:

> … a good solution is good because it is in harmony with those larger patterns. …. A good solution acts within the larger pattern the way a healthy organ acts within the body ….[as]a part of its health. The health of organ and organism is the same, just as the health of organism and ecosystem is the same. And these structures of organ, organism, and ecosystem … belong to a series of analogical integrities that begins with the organelle and ends with the biosphere. (p. 134)

Another scholar terms these phenomena of interdependent wholenesses *self-generating gestalts*. Mathews (2008) considered these "an order of patterning in which elements are arranged into gestalts, and these gestalts fit into larger gestalts, and so on up the scale" (p. 56). Mathews noticed these emergent valences of wholeness are "self-generating rather than externally imposed."

Both Mathews and W. Berry noticed these self-generating integrities unfold and interdepend; they "cannot be exhausted or anticipated by any formula" (Mathews, 2008, p. 56), are not properly conveyed through philosophical contestation, adversarial dynamics, and dialectical critique, and are not exploitable or causal, as might be understood by mechanism or industrial thinking (W. Berry, 1981).

Ulanowicz (2002) argued that these complex patterns express an *ecological metaphysic* that conflicts in every assumption with a Newtonian worldview since ecological complexity is causally open and ecosystems are not deterministic machines but contingent and granular with historical, adaptive, organic, and interdependent propensities rather than causes. Goerner (1995) affirmed as well-supported "the image of an inextricably interwoven ecological universe – self-ordering...wholes," (p. 28). O'Sullivan reinforced T. Berry's description of the planetary context for creativity as recuperative, self-healing, and containing "special powers of regeneration" (1999, p. 205). Schuldberg (2007) echoed this language by describing the fractal quality and patterned chaos of everyday creativity as "reflecting their always original and self-renewing natures," (p. 58). These self-generating, self-similar, fractal emergences existing throughout nature constitute whole systems and can greatly enhance (and reinforce) regenerative creativity.

EARTH REGENERATION AS STRANGE ATTRACTOR FOR COMPLEX CREATIVITY

Earth regeneration in particular points us toward the sourcing of regenerative creativity in ecological complexity. Richards' research on creatives' resonance with fractal patterns from nature (2001a) prefigures the exploration for ecological and biocultural archetypes that my research explores (Hauk, 2007, 2011, 2013b, 2013c). Richards (2001a) researches the aesthetics of "bounded infinity from these domains of nature—and human nature—and the underlying laws that shape them" (p. 261) to understand if the beauty of the sublime and fractal forms of nature could increase flexibility and resilience to later life events. She also suggests that fractals awaken a new humanistic aesthetic, catalysing creative originality, hopefulness, an expansive sense of possibility and reverence for nature, interconnection, awareness of coevolution and compassion "in an evolving system of immense complexity and at time, of unpredictable sensitivity," catalysing "care for the health of this greater whole" of the earth system (pp. 89-90).

Consonant with Richards' findings, my research explores how exposure and inhalation and then perception of these complex patterns from nature increases intelligence and sparks regenerative creativity. Mathews identifies self-generating patterns arising from the interiority of nature—which she terms as conative gestalts—when internalised, as the sources of *gestaltic intuition.* This hearkens back to Cobb's (1977) insights regarding *The Ecology of Imagination in Childhood*: "Intuition, therefore, can be considered to be a type of 'seeing' stimulating in turn the organizing process we call imagination" (p. 47). Why is this so important? Wonder and the ability for novel juxtaposition and meaning-inference from multiple complex systems of embedded information is the source of innovation. Wonder can be described as the state of openness to novel system meshing:

> when it is maintained as an attitude, or a point of view, in later life, wonder permits a response of the nervous system to the universe that incites the mind

> to organize novelty of pattern and form out of incoming information. The ability of the adult to look upon the world with wonder is thus a technique and an essential instrument in the world of the poet, the artist, or the creative thinker (Cobb, 1977, p. 27).

Fauconnier and Turner (2002) identify the *conceptual blends* of two or more complex systems as resulting in multi-scope creativity from multi-scope integration networks. They argue that imagination along with identity and integration are "basic, mysterious, powerful, complex, and mostly unconscious operations…at the heart of even the simplest possible meanings" (p. 6). They demonstrate that "the value of even the simplest forms lies in the complex emergent dynamics [that imagination, identity, and integration] trigger in the imaginative mind." So our thinking and imagination and meaning-making are themselves complex phenomena, and the blending of complex concepts is at the heart of this emergent creative process.

Findings in neuroscience connect the importance of nature-inspired creativity and an attitude of wonder to the sciences as well. For example, Fauconnier and Turner connected metaphor and logic operating by the same complex conceptual blends (2002, p. 84). In *The Poetic Species*, Wilson argued that poets, like scientists, are engaged in enterprises of discovery bound by our relationship to other organisms (1984). Carson and Kelsh (1998) confirmed that a sense of meeting the unknown with primary senses, and having someone to share the experience with, are the critical process. Regenerative design scholar Lyle (1994) verified that "regenerative design involves both art and science not separately but merging together" (p. 38).

Some scholars who have offered a critique of novelty might object to the use of the discourse of innovation and creativity to expound the use of complex, nature-sourced pattern. For example, Bowers (1995, 2012) offered a thorough critique of the addiction to novelty that pervades Western scientism and can be credited with ecosystem and bioculture destruction. Bowers might prefer a reframe around regenerative ecological creativity to instead describe a return to indigenous strategies of deep interrelationship. He would say there is nothing novel about the topic of this chapter. I concur. I am describing a way of being that is natural, wholesome and inevitable for intergenerational, culturally and ecologically embedded cultures. Cultivating regenerative creativity and ecological complexity return us to the ecological and biocultural commons, return us to interdependent relationship with all participants (human and non-human), their relationships, and cycles of life (Bowers, 2006).

My curiosity resides in innovation, or perhaps we should call it earth-ovation, the call that Bowers (2006) names "the need to understand the complexity of the traditions we depend upon in daily life, and use as the basis for developing new and hopefully more ecologically friendly technologies, and advances in further securing a democratic and socially just society" (p. 159). I would even go so far as to extend Bowers' emphasis on intergenerational mentorship to suggest that learning from natural pattern is a way the Earth itself, continually in a state of generativity, can mentor us. Additionally, as I suggest in the ethics portion of this paper, Bowers does point us toward a very fruitful form of creative, complex educational modeling when he suggests it is embedded cultures that can mentor as well.

EXTENDING BIOMIMICRY TO BIOCULTURAL-MIMICRY

I would propose extending biomimicry into the realm of bioculture to produce a construction of biocultural-mimicry in order to take up Bower's challenge to learn from (rather than take from) indigenous wisdom systems. Maffi and Woodley (2010) and the work of TerraLingua have established the connections between places of great biological and linguistic diversity, establishing the need to preserve and cultivate biocultural diversity as well as biodiversity. Bioculture represents the dense interweavings of human-nature, co-evolutionary cultures, and wisdom. We might call these cultural patterns that, like ecological patterns, serve as multi-scale fractal evidence of complex adaptive systems. In this case, these diverse and unique human cultural patterns and practices help maintain complex ecosystems in which they are embedded and with which they thrive. The traditional ecological knowledge (TEK), ethnobotany, and biocultural diversity movements offer deep examination and insights of some of these patterns, designs, and connections. Cajete (2000) articulated the indigenous wisdom of mutual experiencing: "the continual orientation of Native thought and perception toward active participation, active imagination, and active engagement with all that makes up natural reality… a part of the Earth mind" (pp. 27, 30). Cajete also explained:

> They experienced nature as part of themselves and themselves as part of nature. They were born of the earth of their place. …This is the ultimate definition of being 'indigenous' and forms the basis for a fully internalized bonding with that place. (pp. 186-187)

Citing traditions spanning more than 70,000 years, Cajete called this Native "ensoulment of nature… a *geopsyche*,…the inner archetypes in a place… that interaction between the inner and outer realities" (2000, pp. 186-187). This geopsyche, inner archetype, interior bonding, and co-presencing are another articulation of what Mathews (2008), as mentioned previously, calls gestaltic conativity.

T. Berry exhorted us: "The human is fulfilled in the earth. The earth is expressed in the human" (1999, p. xv). Modern articulations of this impulse include terrapsychology (Chalquist, 2010), place-based education (Gruenewald & Smith, 2008), as well as the resurgence of TEK (see, for example, Cajete, 2000). Additionally, ecopsychologists are actively engaged in distilling pattern languages not just of wild nature without humans, but "of deep and meaningful patterns of human interaction with nature, many of which emerged through tens if not hundreds of thousands of years in our evolutionary history" (Kahn, Ruckert, Severson, Reichert, & Fowler, 2010, p. 60).

SEEDS OF WISDOM

We are people, living in a time of seed-making. Seeds are distillations, often coated for endurance, taking the essence of the make-knowing and condensing it into a portable form. In the coming times of increasing turbulence and the unknown, a time of industrial culture's consequences, when it might be that what grew well or provisioned us before will no longer thrive, we have an opportunity to make seeds, to carry seeds, to teach people how to make and carry seeds of biocultural pattern and wisdom.

Seeds are an example of complexity compressed. Similar to algorithms for compressing computer files, language and thinking can also be compressed. Fauconnier and Turner (2002) spoke about compression in blending networks and how they operate on a surprisingly small set of relations rooted in fundamental human neurobiology. They saw conceptual blending as "an instrument of compression *par excellence*" and noted "one of the overarching goals of compression through blending is to achieve 'human scale' in the blended space, where a great deal of conscious manipulation takes place" (p. xiii). Rowland (1999) offered a three-faceted seed as a root metaphor for educational designing, learning, and systems, and found the chaos theory worldview as a potential convergence-creator between objective and constructive views.

The strategy and content of biocultural relations and insights (that are embedded in indigenous cultures' wisdom traditions) are examples of compressed wisdom seeds worth emulating. So the patterns of non-human nature as usually implied by biomimicry and also the patterns of human-nature relations from intact multigenerational nature-embedded wisdom systems are worthy of study and mimicry.

The traditional ecological knowledge (TEK) movement is a good example of capture and respect of indigenous biocultural wisdom (Martinez, 2012). The place-embedded specifics of biocultural wisdom are worthy of extensive study and learning, and so are the patterns and strategies that these collaborative, complex systems embody. Therefore, I propose that one area of study in regenerative creativity would be the archetypes or fractals of relationship and strategies of wisdom seeds offered by ecologically-embedded cultural folkways. This would provide, perhaps, a more detailed primer on the concept of "all my relations" (T. Berry, 1999, p. xiii). Extending Fauconnier and Turner (2002), learning how to think and design with poetry, folk sayings, mythology, and lifeways can carry generative, compressed double-scope creative blends. This can change our world and re-align us with the regenerative creative complexity of human-embedded cultures as well as help us learn to distill and carry forward life-giving pattern to share with the future earth system.

Parallel to the way that ecological fractals such as branching, vortex, hive, and flow can kindle regenerative creativity (Hauk, 2007, 2013b, 2013c), oral and indigenous wisdom systems and traditions will surface as biocultural fractals that similarly promise to return our innovation to earthly regenerativity. In fact, some research indicates that creative works sparked by these ecological and biocultural system-coherent integrities might be necessarily more renewing and ethical.

INDICES OF SUCCESS

In terms of regenerative creativity, it is insufficient though important to provoke or enhance fluidity, flexibility, elaboration, and other traditionally recognised symptoms of creativity. The time of intense need beckons for what Madjar, Greenberg, and Chen (2011) name radical or divergent creativity rather than incremental creativity. Additional factors of group regenerative creativity will inspire literacy in the patterns of biocultural wisdom systems. These underlying relational archetypes might begin to expand traditional factor analysis of non-domain-specific creativity to include regenerativity to extend beyond conceptual blending strategies such as topology, pattern completion, integration, maximisation of vital relations, intensification, and maintenance of the web of links (Fauconnier & Turner, 2002). In other words, working with these archetypes does more than produce innovation *per se*, it produces ethical, regenerative innovation that in both content and form are creatively effective in the context of earth regeneration.

A direction for future work, currently underway, would be the development of a Transdisciplinary Regenerativity Index to help track and compare the complex adaptive systems regenerative potential of various creative products (Hauk, 2013a). Additionally, future work could extend this chapter's tracing of chaotic dynamics of creativity's multiscale emergence to include other complex adaptive and living systems elements. For example, how does regenerative creative emergence exhibit or how can it be optimised by distributed resilient systems biomimicry dynamics such as response diversity and ecological memory (Ryan, 2013).

ETHICAL CONDUCT IN REGENERATIVE CREATIVITY

The type of regenerative creativity cultivated by interaction/immersion in natural and biocultural pattern produces resilience and shifts values and ethics as well as catalyses and sustains restorative, novel, and adaptive solutions. This interposing time of glocal crisis requires all three of these fruits of regenerative creativity: ethical values shift, novel and restorative designs, and resilient cultures.

Regenerative creativity increases ethical conduct and produces designs that regenerate. Bowers (2006) made the case that alignment with complex natural cycles will produce cultural practices that are regenerative: "The importance of knowing the life cycles of the animals, plants, and other participants in the commons (bioregion)…leads to an emphasis being placed on cultural practices that are more attuned to the life-renewing characteristics of natural systems" (p. 96). What Bowers suggests is important. In fact, as he promises, and Mathews confirms, the fruit of this way of perceiving is moral reciprocity and ethical conduct. Bowers described it as "a way of experiencing place in a way that combines a complex knowledge of local ecosystems with the practice of moral reciprocity" (p. 94).

Ecofractals and biocultural fractals form the core of ethical regenerative studies. Mathews (2008) proposed that time and *creative co-action* with the essential gestaltic integrities of nature, in fact, *induces moral commitment*. She suggested that co-active synergy induces the moral point of view. In particular, Mathews explored how creative connections with natural pattern can persist beyond moments of performance (as in activities such as the Council of All Beings). Mathews argued that, because creativity is a result of the internalised gestaltic patterns of nature, becoming imprinted with these patterns "will ensure that creative thinkers will incline towards a custodial attitude towards nature" (p. 57). In fact, Mathews highlighted the self-similarity between (re)generativity in nature, creativity, and an ethic of care. This case of self-similarity and fractality finds internalising the hidden order of the cosmos, "from within the calyx of nature," produces similar patterns of creativity and caring.

Mathews envisioned an educational system resulting from this insight:

> If people could be exposed in childhood to the kind of experiences that would result in their becoming imprinted with the inner organisational dynamics of nature, then this would produce a society of creative individuals whose activities in every field of praxis would be consistent with, and tributary to, the unfolding of nature….It would instead call on us to restructure education generally, at school level as well as at university level, so that all students would be routinely afforded opportunities for the kinds of experiences in nature that would result in their becoming imprinted with the inner organisational patterns of the cosmos. (pp. 57–58)

The vital practices of emotionally and socially engaged ecoliteracy confirm this connection between understanding how life is sustained by nature and the development of empathy for all life forms (Goleman, Bennett, & Barlow, 2012). It is in fact my proposal that experiences with these eco- and biocultural fractals would be at the very heart of earth regenerative studies.

Ulanowicz (2002) made a case for autocatalysis (autopoiesis, self-generation) in ecological complexity. He demonstrated mathematically that feedback loops from creative autopoiesis reinforce human-nature mutualism and continue to increase ethical alignment. He found that emergence and autocatalysis are related to a selective pressure (feedback loops) specifically from mutualism. These tend to shape and reinforce the "habits" of the system: "(1) Autocatalysis serves to increase the activities of all its constituents, and (2) it prunes the network of interactions so that those links that most effectively participate in autocatalysis tend to dominate over those that do not" (p. 8). One can interpret this aligning function of regeneration to include providing positive/directive pressure for mutualism and ethical alignment. Jardine (1998) suggested that an integrated curriculum with students learning to live with the self- "'organisation' *originating from things themselves*…their inviolable integrity… generates a loving interest in the Earth and others" (pp. 80-81). Craft characterised this kind of ethically, socially, and ecologically aligned multiscale creativity as wise creativity (2010).

What I am describing as complex regenerative creativity increases ethical approaches to design and governance, for example in user-centred design, and protects against globalisation and imperialism. Complex adaptive systems mathematicians such as Minati and Pessa (2006) focused on complex emergence and demonstrate this shift. Design moves to a systems orientation and the user is no longer a passive consumer. They contended that, "now, on entering the systemic age, an age of complexity of learning, adaptive, self-organising systems, the crucial role of the user is no longer a cause of weakness, but of robustness" (p. 346). By solving problems for the people who are having them instead of focusing myopically on "the problem" out of its complex context, better and more ethical solutions arise. Further, they argued that complex and emergent learning approaches and designs protect both against imperialism and consent manipulation (p. 347). They found that, for emergence, systemic openness, and logical openness, through the mutual use of different levels of models:

> *The ethics of such an interaction between systems* regards the possibility of mutually influencing their respective behaviors, while respecting the systems' autopoietic processes i.e. *system identity…. An ethical process of interaction must be based on co-creation, co-designing whilst respecting the autopoiesis of the system.* Interaction systems are not assumed to simply establish a set of systems or lead to one dominating or enclosing the other. *Systems interact making emergent new multiple-systems, as in Collective Beings, and not just a new system.* (p. 348, emphasis all as in the printed original)

This mutual consent echoes the mutualism and reciprocity that Bowers mentions and the cultivation of an earth compassion that Mathews demonstrates.

Richards also found ethical values sourced from complex creativity (2001b). Specifically, Richards argued that holism and interconnectedness surface when the dynamic interactions of unique open systems of humans and creativity are the focus (2001b, p. 257). She "examines ways a brain organized according to principles of nonlinear dynamics (chaos theory) may initiate originality" (p. 263). She highlighted, sudden creative shifts "can begin to alter values and our way of life toward a sustainable world culture, and soften the multiple catastrophes for which we are now headed" (p. 263). Richards is suggesting that fractal/regenerative creativity encourages wholeness and connectedness that can move values into ethical alignment. She also suggested that chaotic creativity can build reserves for resilience in times of planetary system collapse.

In fact, the extension of biomimicry into biocultural-mimicry and regenerative creative engagement with these patterns can help avoid some of the detrimental decontextualisation of solo functional pattern plucking and lack of systems orientation to which biomimetics can fall prey. Neither biomimicry or biocultural-mimicry's greatest call is to extend nature and bioculture as sites of colonisation, mining, and extraction for capitalist invention, production, and consumption. O'Sullivan warned that vision is required "that resists the corporate visions of an infinitely exploitable planet" (1999, p. 201). Craft (2010) echoed this concern, to avoid market-driven, growth-devoted *neophilia* for aligned and possibility-oriented wise creativity. It is possible that the systems-orientation and social and ecological insights of regenerative creativity and biocultural mimicry can in fact infuse a more grounded, contextualised, systems view into the practices of biomimetics and also extend its purview to human-cultural fusion. Montuori calls this kind of transdisciplinary approach to complex creativity, for example in the field of social creativity, a metaparadigmatic approach that contextualises and connects (2005, p. 155). The earlier discussion of the emergent effects of self-organisation from recursive regenerative creativity generating ecologies of creativity, cultures of innovation, empathy, and collaborative emergence are relevant here. S. Sterling (2007) saw these in complex emergence generating a "connective cultural consciousness" aligning with what some have theorised as the Great Transition, the Great Turning (Macy & Johnstone, 2012), and what O'Sullivan mentioned as T. Berry and Swimme's ecozoic era (1999). Similarly aligning with ethics of mutual reciprocity and care, both connective and collective, Dolby (2012) affirmed that these connections increase empathy and justice.

The very patterns of nature and nature-culture embed and evoke ethical conduct and regenerative processes. Re-embedding ourselves in the vital and vitalising patterns of Earth pushes us toward life-enhancing outcomes. Wangari Maathai (2010) named this rediscovering of the love of nature that animated our ancestors as the spark for reforesting entire ecosystems and transforming army troops to grove tenders.

CONCLUSION

Creativity can be complex and regenerative. As the earth works through us, the emissive and transformative dynamics of chaotic and complex creativity promise to generate and sustain the generation of new/ancient designs of emergent wholeness. In particular, transdisciplinary creativity opened in contexts of wonder and inspired by natural pattern promises to catalyse the human capacity for designing solutions that renew and replenish. These dynamic patterns from nature represent fractal archetypes from ecology as well as biocultural, human-nature collaboration. Renewing patterns create and awaken wholeness-making, diverse and divergent, regenerative design that aligns with an ethic of earth care, reciprocity, and mutualism.

We are called to optimise educational contexts for this life-giving and restorative complex creativity in order to nurture and awaken Earth designers and creators. We are invited to create and sustain edges of (learning) chaos where dense interactions between diverse creatives with sensitive dependence on initial conditions flourish in far from equilibrium states—including divergence-nurturance, flow and purpose, and a capacity for ambiguity. These spark amplifying feedback loops and sustain creative emergences. Together, our collective creativity emerges as a fractal mirror of nature's generative wholeness.

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TODD JUHASZ

PARETO OPTIMUM EFFICIENCY BETWEEN CHAOS AND ORDER WHEN SEEKING CONSENSUS IN URBAN PLANNING

Urban planning is a diverse field that encompasses land use, transportation, economic development, environmental planning, and more. Many planners are generalists who often call on specialists to solve certain specific problems. Whatever the specialty brought to bear on an issue, a holistic approach to analysing problems and prescribing solutions is central to planners' work. To see this work realised, planners must navigate through political and public approval processes that can either derail the best intentions of well meaning planners or yield results that optimally reflect the goals, objectives, and desires of the community. This chapter examines two planning case studies that wound their ways through the political and public approval process with varying results. What emerges is an understanding of the types of approaches that allow plans to be formed in a complex fashion while remaining tethered to the financial, physical, and political opportunities and constraints within the system where the plan takes shape. Finally, suggestions are made to prepare better urban planning students to manage the public and political processes upon graduation.

What is urban planning? It is a profession that actively plans and manages the health and quality of life in urban spaces—cities and their suburbs, small towns, and rural villages. Urban planners manage the development of raw land sites and the physical form of cities as diverse as Beaverton, Oregon and New York City. Planners view the city as an organism and look for holistic solutions that further optimal policies and design in support of the city's development. Also, planners anticipate how a city will function and how it will look as it develops or redevelops through time. For example, planners anticipate how a series of buildings will fit together aesthetically and how they will be linked to the infrastructure of streets, sewers, water lines, and electricity. Planners determine how these structures "fit" into the local economy and what demands might result for the types of services that intended buildings were designed to provide (residential, commercial, mixed-use development). Planners also ascertain who the potential users of the structures will be and how the spaces between buildings are used. Correspondingly, planners gauge what road networks, highways, buses, and other forms of mass transit will bring residents to and from these structures. In addition, secondary impacts must be managed; for example, the planner estimates the impact of construction and how the surrounding environment (greenhouse gas emissions, storm water run-off) within a defined distance from the building will be managed over time. Other

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 123–140.

secondary impacts to be considered include how the development as a whole affects the residents in relation to job opportunities, noise, retail opportunities, community character, and cost of living, among others factors.

The early stages of a planning process can take many forms, though a typical process involves a series of planning team meetings to determine the project's goals and objectives. While continually refining the concepts, the team then develops a series of concepts that achieve the stated goals and objectives. During the process, the team also looks for flaws in logic and unintended consequences that may arise should a concept be carried through preliminary design and beyond. Once skeletal, sketch-level concepts are developed, the team seeks approval from public officials (elected and/or appointed) prior to starting the public approval process.

PLANNING AND COMPLEXITY THEORY

When attempting to understand the dynamics that arise when managing urban planning projects and the political process, complexity theory provides a framework for understanding the underpinnings of how a project either emerges with general consensus or is scrapped and abandoned after reaching impasse. The edge of chaos is a helpful construct developed by complexity theorists Langston and Packard (see Kauffman,1995; Waldrop, 1992). Further, a way of shaping a community's desires while seeking favorable political outcomes, should be envisioned through a lens in which planners can devise outcomes that seek balance along a continuum between two diametrically opposed poles. At one end can be found chaos and at the other, reductive order (Kriz & Cooke, 1997).

At the ordered end of the spectrum one often finds stereotypical bureaucracy where decisions are ruled by routine and logic, often tainted by organisational dogmatism. Such an organisation is ordered from the top down with latitude for decision making driven by what is acceptable within that rigid framework. In contrast, on the chaos end of the spectrum, one finds a messy and varyingly chaotic public outreach processes. The level of chaos is propelled by the number of stakeholders, the level of trust among stakeholders, the divide between desired outcomes, and the degree to which parties are willing to find common ground. More important to the process is the willingness of political actors to listen, compromise, and address the varied stakeholder concerns while meeting overarching planning goals and objectives.

The planner's role in this process is to keep an eye on the most important goals and to identify, in order of importance, issues to be resolved and design elements to be incorporated. Then, the planner's role is to mediate among all participants. The desired outcome is to keep the conversations moving in that zone of complexity where the process is messiest. Within this messy milieu, political actors and stakeholders seek to bring order, request concessions and revisions, suggest new designs, or in many cases, attempt to derail the process. The process is messy and the potential pitfalls are many.

To summarise, when urban planning initiatives are given the green light by elected and appointed officials, the greatest task is managing a desire for order by public officials seeking an expedient and desired outcome while dealing with the competing voices of stakeholders within the public approval process. In processes where expectations are managed and compromise occurs with a variety of issues over time, the greater the likelihood that the resulting plans will reach implementation.

PLANNING AND THE POLITICAL PROCESS

Often, ambitious initiatives are never implemented because of urban planners' desires to reshape the landscape conflict with the political will of public officials or find extensive opposition from interest groups, businesses, and other stakeholders. In other cases, direct benefits coupled with positive externalities when compared to the cost do not appear sufficient for public officials to support the initiative. Worthy projects also fail to garner support when project benefits do not materialise during a four-year election cycle or market conditions change between conceptualisation and implementation. However, most often, the inability to complete a particular project arises from a failure to understand the intricacies associated with managing the politics of planning (Benveniste, 1989).

When undertaking a planning initiative, public officials tend to hold the reigns tightly and demand an overly ordered process in an attempt to control outcomes. In turn, the attempt to seek orderly outcomes typically meets a chaotic cacophony of demands; a stream of informed as well as distorted objections arise from stakeholders with diverging, competing interests along with a slew of helpful suggestions. To reach consensus over time, planners must manage the push-pull between chaos and order and seek the pareto optimum balance at the interface between chaos and order.

In my particular set of experiences, I have served as a generalist urban planner; however, my focus over the last few years has been transportation planning. Examination of the following two transportation planning cases demonstrates how a political process was not managed optimally and a project shelved, and another project for which the optimum balance between chaos and order was struck, leading to consensus and favorable outcomes.

CONGESTION PRICING: NYC 2007

Congestion pricing is a method used to reduce vehicular traffic by charging a fee to road users during peak hours of demand. The user fee may vary by the time of day and day of the week with highest fees charged during peak periods of demand and lower or no fees charged during less demand periods. Instead of seeking a supply side solution like building new roads, congestion pricing seeks to address demand by increasing the rate at which a large percentage of users choose other travel options. Congestion is managed by pricing some road users out of gridlock in an attempt to reduce greenhouse gas emissions, reduce the vehicle-capacity ratio, and improve the quality of life for residents living near heavily congested roadways.

Congestion pricing has been implemented successfully in Singapore, Stockholm, and London. In Manhattan, grassroots support for the implementation of congestion pricing greatly increased after London's successful implementation of cordon pricing in 2003. Seeing London's success, vocal proponents from a small group of local elected officials, civic and advocacy groups in New York City such as the Straphangers Campaign, Transportation Alternatives, the Regional Plan Association (RPA), and the Powerful Partnership for New York City–were representing large businesses within the city–were were all early vocal advocates for the implementation of congestion pricing policies.

After New York City Mayor Michael Bloomberg was reelected for a second term in 2005, he made the decision to develop a long-term land use plan for the city. The mayor chose to include ambitious plans to introduce congestion pricing partly in response to the clamor from the aforementioned civic leaders and advocacy groups and partly through his own desire as mayor to display leadership on climate change initiatives by making New York the first North American city to implement an area-wide congestion pricing program. The mayor also stated that the decision to develop the plan was a way to partially "respond to continuing population and job growth coupled with the city government's growing difficulty in finding properties suitable for facilities as diverse as new schools and trash transfer stations" (Schaller, 2010).

In April of 2007, Mayor Bloomberg unveiled an ambitious set of sustainability plans called PlaNYC that included 16 proposed transportation initiatives. The core of the plan called for the implementation of cordon-based congestion pricing; congestion pricing was the only component of the PlaNYC requiring approval by the New York State Legislature. The cordon pricing proposal required drivers entering the lower half of Manhattan to pay an $8 fee for entering the cordon zone between the hours of 6 a.m. and 6 p.m. on weekdays.

New York City applied to be part of the United States Department of Transportation's Urban Partnership Program, which would allocate money to cities that were willing to "fight urban traffic congestion through tolling programs, express bus service or bus rapid transit, telecommuting or technologies designed for the purpose" (United States Department of Transportation, 2007). In June 2007, the United States Department of Transportation (USDOT) stated that out of the nine finalist cities applying for the program, New York City was the furthest along in its traffic reduction planning and the city was eligible for up to $500 million for funding their congestion pricing plan. Since the final funding decision would be announced in August, the Secretary of the USDOT wrote to then Governor Eliot Spitzer and stated that if approval was not met by July 16, it was unlikely that New York City would be selected (Arden & Patrick, 2007). In response, Spitzer signed a bill that authorised New York to apply for at least $200 million in federal funds.

On August 14, 2007, the USDOT awarded $354 million to New York City from the Urban Partnership program. It was the largest of the five grants awarded to

American cities. Only $10.4 million was allocated for launching the congestion pricing program and $2 million for research. The rest of the grant was to fund transportation infrastructure and services: $213.6 million to improve and build new bus depots, $112.7 million to develop bus rapid transit routes, and $15.8 million for expanded ferry services (Schaller, 2010).

Though it was not without controversy among certain groups in and around the city, the mayor's proposal appeared to have momentum by early 2008. A Quinnipiac University poll showed that two thirds of New Yorkers supported the bill (Quinnipiac University, 2008). The proposal also had strong support from prominent officials including the governor of New York State, the state senate majority leader, as well $354 million as an identified source of funding (Lynch, 2010). To secure the funding, the New York State legislature had to approve the cordon pricing plan by April 7, 2008. In March of 2008, the city council voted in favor of the tolling plan by a count of 30–20. The only remaining necessary approval was from the state (Lynch, 2010).

The mayor's proposal was introduced in the state legislature in June 2007, but the Legislature adjourned its regular session without taking action. In mid-July, under pressure from City Hall, newspaper editorial boards, civic and other groups, the legislature reconvened and created a 17-member Traffic Congestion Mitigation Commission. The Commission was tasked with studying both tolling and non-tolling approaches to controlling congestion in the southern half of Manhattan. In January of 2008, the Commission recommended a modified version of Bloomberg's original proposal. The Commission plan removed neighbourhoods on Manhattan's Upper East and West Side from the pricing zone, eliminated outbound fees so that the congestion pricing fee would be charged only on to in-bound vehicles, and replaced the intra-zonal fee with taxes and surcharges on Manhattan parking garages and taxi trips (Schaller, 2010). Additional concessions were made by members of the Commission, and the proposal passed with a vote of 13–2.

While the plan was supported by the mayor, newly-elected Governor Patterson, and many civic, labor, and advocacy groups, there was vocal opposition from elected officials and civic groups in the four boroughs outside Manhattan. The most vocal opposition came from Queens and southern Brooklyn. These groups argued that Queens and southern Brooklyn residents were significantly underserved by transit resulting in a much higher percentage of car-bound users than Manhattan residents and questioned the likelihood that money from congestion pricing would actually be used for transit improvements. The opposition questioned the inequity in the plan that would have Queens and Brooklyn residents charged an $8 fee to cross East River bridges when there was currently no charge, and New Jersey residents would pay nothing beyond the existing $8 dollar toll to traverse the Hudson River. With strong opposition from assembly members from the outer boroughs, assembly Democrats stalled voting as the deadline for federal funding approached. Without the required legislation, the federal funding deadline passed, and the bill never came to a vote.

Ultimately, why did the mayor's proposal fail despite the backing of many influential politicians and advocacy groups? According to Bruce Schaller, Deputy

Commissioner for Planning and Sustainability for the New York City Department of Transportation:

> The short answer is that a relatively small group of auto users believed that congestion pricing was against their best interests. As with many large highway construction projects in the 1970s and 1980s, the extensive approval process required for congestion pricing offered auto users an avenue to block action. The intensive interests of one group were thus able to overcome widespread public support. (Schaller, 2010, p. 7)

In other words, the view of certain public officials is that many residents acted in a self-serving manner at the expense of furthering climate change goals. I posit that the failure of the initiative stems from numerous factors, one of which was the mayor's lack of engagement in sufficient public outreach to the right constituents before unveiling the plan. Much of the polling and attitudinal research was done within Manhattan, the most affluent borough of the five that constitute New York City and the borough least likely to rely on personal transportation. In addition, early focus group work and attitudinal research focused on Manhattan, largely at the expense of other boroughs. So when the plans were announced, the majority of Manhattan residents were in support of the program and much of the press hailed the bold step towards reducing congestion, greenhouse gas emissions, and quality of life for Manhattan residents.

On the other side of the argument were residents of other boroughs, especially southern Brooklyn and large parts of Queens, that are not well served by public transit. In comparison to Manhattan, many more of the residents of these boroughs rely on personally owned vehicles to get to work in the cordon pricing zone and have limited incomes. To these residents, a daily road user fee was seen as a substantial burden. Further, the argument that funds generated from congestion pricing would be spent on new transit, including a potential new subway line, was met with skepticism because decades had passed without the construction of new lines to underserved neighbourhoods in southern Brooklyn and many parts of Queens. In the interim, residents did their own cost-benefit analysis, not based on the goals of congestion and greenhouse gas reduction but rather on how citywide policies affect their individual lives.

In Manhattan, commuters have easy access to subway and bus lines and tend to have substantially higher incomes. So, for the majority of these commuters, there would be no impact on those who took mass transit, while drivers with higher incomes originating in Manhattan are much more likely to view a toll of $8 in support of improving levels of congestion as a minor inconvenience.

After the bill failed to reach a vote, many framed the issue as an impasse between drivers and non-drivers, rather than as one of class-based tensions involving income and location between affluent residents of Manhattan and the poorer outer-boroughs. As previously stated, not enough time was spent gathering attitudinal research and determining travel demands of those in outer boroughs and attempting to find ways to address concerns prior to announcing the intent to implement cordon pricing (Taylor & Kalauskas, 2010). Once the proposal was launched, planners and politicians had the unenviable task of attempting to gain the trust of impacted drivers in outer boroughs after it appeared that City Hall had acted in bad faith.

NYC Cordon Pricing: Chaos and Order

Returning to complexity theory, the mayor and supporters attempted to use logic and reason to explain why the plan should be supported on its merits and insufficiently considered the needs of individual communities and attempted to force top-down order on a City that was not ready to frame the argument in the way City Hall and others would have liked. While most would agree that a reduction of greenhouse gas emissions is a worthy goal, such concerns take a back seat when a family is living on a budget, and a fee of $8 per day has a significant impact on that family's quality of life. It also illustrates that humans are complex and make decisions based on a number of factors and that logic is often not the driver. Or to frame it another way, the existing power structure's logic is not the same set of logic as a large subset of NYC residents.

Given that the mayor and other public officials failed to effectively and comprehensively gauge the needs of the entire city's population early enough to meet the federal funding deadline, it is no surprise that the public process devolved into chaos and the bill sat as a dead letter in Albany.

PORTLAND, OREGON, SEPTEMBER 2010

In early 2010, the Oregon Department of Transportation (ODOT) agreed to partner with the City of Portland's Bureau of Planning and Sustainability (BPS) and the Portland Bureau of Transportation (PBOT) to resolve interrelated issues. ODOT was committed to improving conditions on the freeway and at the interchange interfaces with local surface streets. The section of I-5 between Interchange I-84 to the I-405 to the north is known as the Rose Quarter area and was built in the late 1960s with two lanes running north and two southbound.

The width of the freeway had not expanded despite traffic having more than doubled and the population of the metropolitan area having grown by more than 50% resulting in heavy congestion for most of the day. In addition, this two-mile stretch of freeway runs through the heart of the North/Northeast (N/NE) Quadrant. Portland is divided into five quadrants and had the highest crash rates in the state. The high crash rates resulted from a preponderance of rear-end and sideswipe collisions. These collisions were due to closely spaced interchanges where motorists had to compete with other drivers within a short distance/decision making horizon to either maneuver over to the centre lanes and into the flow of traffic or compete with motorists seeking to exit the system from outside lanes via the nearest interchange. Along with the highest crash rates and congestion in Portland, the freeway was

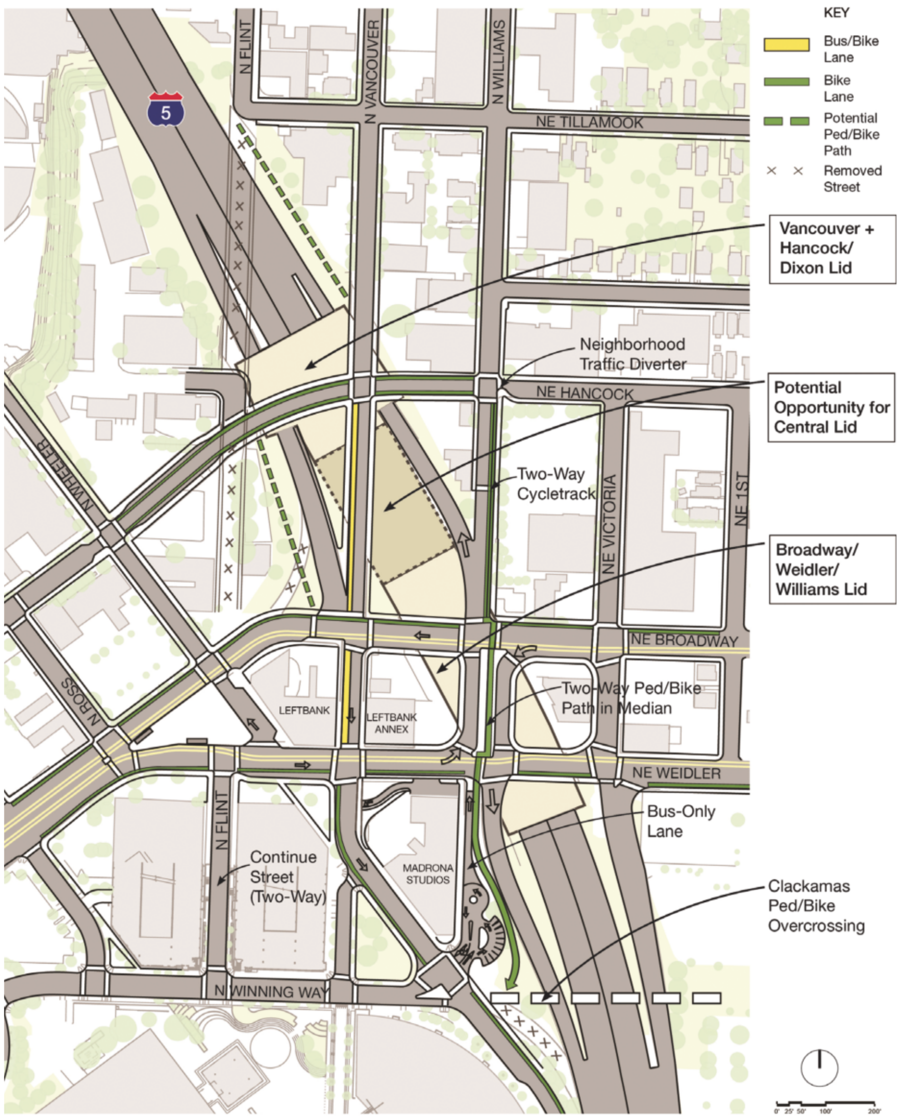

Figure 1. Project area: Enlarged "box" area of the recommended concept.

designed without "shoulders" or breakdown lanes in which disabled vehicles could be moved out of the flow of traffic until emergency response vehicles arrived. With disabled vehicles left in the free flow lanes during peak periods, the resulting additional congestion created gridlock for miles. Finally, political leaders at the state level wanted to address the fact that this stretch of I-5 was ranked as a top 60 national freight bottleneck, severely impacting the inter- and intrastate flow of goods along the entire length of the West coast from Mexico to Canada *Commercial Carrier Journal*, 2011. Without plans to widen I-5 beyond the two-mile boundary of the project, the most planners and engineers could do to improve the freight bottleneck was to reduce localised, operational friction. In other words, planners wanted to create easier access to on and off ramps for freight originating or destined from Portland and allow a slightly higher average travel speed once on the freeway for drivers in the far outer lanes within the two-mile study area.

One caveat for ODOT leaders and elected officials when making the decision to support the project was preventing the freeway-widening project from being billed as a wholesale freeway-widening project connecting the Rose Quarter section of I-5 to the highly controversial Columbia River Crossing project that was underway to the north at the border between Oregon and Washington states.

The City and ODOT wanted to partner on improvements to the freeway and land uses within the N/NE Quadrant of the city. The BPS and PBOT were working on an update to the city's 20-year Central City Plan or "Central City 2035" starting with the N/NE Quadrant of the city. Given that the I-5 freeway bisected the Quadrant, state and city leadership saw obvious advantages to partnering because what happens on the freeway affects the livability of residents on the local street network, while additional trips generated from new developments potentially impacted operations on the freeway facility. Assuming the project made it through agency and public approval processes, the state and city would need to identify as much as $500 million in funding to support safety, operational, and other improvements. The desired final products would include a mutually agreed upon set of documents: one being an I-5 Facility Plan and the other a N/NE Quadrant plan to be nested within the Central City 2035 plan update.

When discussions began about partnering on the projects, there was some apprehension on the part of ODOT, BPS, and PBOT because the city and state had partnered on several occasions over the previous 20 years in attempt to reach agreement on a mutually beneficial set of improvements to the freeway and surrounding landscape but agreement was never achieved. One important point is that each of the proposals over time diminished in size, cost, and scope. The hope was that with a renewed focus on an even smaller geographic area, while seeking more pinpoint improvements, the current process would lead to greater opportunity to reach consensus and implementation.

Descriptions of proposals from the 1980s when the first designs were discussed illustrate how the scale, cost, and scope diminished over time. Plans included the addition of many large ramps, frontage roads, and the widening of the I-5 freeway to the Oregon-Washington border with a price tag upwards of a billion dollars. Other proposals included burying the I-5 freeway under the Willamette River and under the waterfront on the east side of the city, then having it surface near the Rose Garden Arena. Again, this proposal would have cost billions and would have resulted in major disruptions for years as the project was under construction. Besides the high price tags, each of the proposals would have had severe land use implications to include extensive right-of-way acquisitions, changes to the Portland skyline, major traffic disruptions, economic development impacts, and requirements for extensive environmental remediation.

Prior to the current process, the last time the city and state worked together on issues related to the freeway and surrounding land uses was in 2007 when an internal planning workshop was held. At that time, several promising concepts were generated that focused only on the two mile section of I-5 and adjacent land uses. The rough engineering estimates for the proposals ranged from a more modest 400 to 800 million dollars. No consensus arose from the process, but the resulting concepts were used by stakeholders, elected officials, and agency officials as a starting place to gather input on new freeway designs that better met local and state objectives.

Before the city and state team first met on the current process, a professional mediator was hired to facilitate internal discussions, to resolve impasses that would likely arise among state and city agencies, and to manage impasses during public forums as the range of competing issues were likely to be extensive both within the team and outside of it.

When the state, city agencies, and mediator finally met, all participants came with desired outcomes driven by their individual missions and leadership. The agency participants and their initial desired outcomes included the following.

For Oregon Department of Transportation (ODOT), the desired outcome was to improve safety and operational issues on the freeway though the addition of auxiliary lanes and full shoulders through the study area, the construction of a raised, braided ramp (two intertwining ramps that would be elevated against the city's skyline), and a series of potential other solutions involving a large increase in the freeway facilities' footprint.

For the City of Portland's Bureau of Planning and Sustainability (BPS), the desired outcome was to complete the N/NE Quadrant portion of the Portland Plan update on time. In regard to the freeway, BPS wanted to limit the amount of additional freeway space and find ways to connect the east and west sides of the freeway together so bicyclists, pedestrians, and motor vehicle traffic could more easily bridge the freeway divide.

For Portland Bureau of Transportation (PBOT), the desired outcome was for limited changes to the freeway, including no additional lanes. As an alternative, PBOT wanted to focus on increasing bicycle, pedestrian, and mass transit usage while decreasing trips by single occupancy vehicles.

In August 2010, ODOT and the city agencies officially created a Project Sponsor Chartering Document that outlined the purpose, products, and coordination guidelines for the project. The chartering agreement also outlined a framework that included the general goals and objectives. The ODOT and the city agencies then asked stakeholders, based upon a broad range of interests, to serve on a 30-person panel called a Stakeholder Advisory Committee (SAC); ODOT and the city agencies agreed to meet with the SAC once a month minimally. A Technical Advisory

Committee (TAC) was also formed, and it was comprised of agency officials and other experts to serve as monitors and to make suggestions if course corrections were needed.

While the public process was gearing up, the initial internal team meetings tended to be contentious and heated as all agency actors and the mediator attempted to sway the process in a direction that most favorably aligned with agency and individual goals. At one point, relations became so heated that a second mediator was hired to resolve the acrimony that had developed among the agencies and the original mediator. Eventually, tensions eased to a degree, and the team spent more time focusing on the desires of non-involved agency stakeholders engaged in the concurrent public process. Essentially, the stakes were too high to allow the process to fail, and the team—exhausted from endless bickering—began to move away from strict adherence to agency positions towards allowing the seemingly chaotic ideas from agency members and other stakeholders to percolate rather than being dismissed immediately. The hardened positions and rhetoric driven by the leaders of each agency softened, and new ideas trickled back to the top of each respective organisation. Therefore, leeway was afforded to allow the public process to run its course with a significantly less rigid and excessively ordered set of prescribed outcomes.

The Process: The Stakeholder Advisory Committee and Public Outreach

ODOT and the city undertook a comprehensive public process that was complete with a diverse and inclusive SAC, a professional mediator, numerous outreach events in the community, study area tours, and many briefings with potentially affected stakeholders and property owners.

Integral components of the process were the knowledge and input from the 30-member SAC whose membership brought wide-ranging perspectives in the study area to advise the partner agencies at each step of the process. The SAC, which included members representing neighbourhood, business, bicycle, pedestrian, transit, freight, rail, event facility, and property owner interests, was one of the primary means of ensuring that the public had multiple opportunities to provide meaningful input into the planning process.

The first SAC meeting was held on October 14, 2010, at which time collaboration principles were discussed and agreed upon by the SAC. These rules governed the decision-making process for each determination made over the duration of the project. If full consensus could not be found, a simple majority of votes would serve as a collective "yes" vote on a specific set of issues. The collaboration principles were adopted in March of 2011.

With the adoption of collaboration principles, the team, consulting architects, engineers, and planners met with invited members of the public, stakeholders, and SAC members for two *charrettes*, one land use based and the other freeway/transportation focused. A charrette is a collaborative session in which a group of designers draft solutions to problems with input from citizens, stakeholders, agency officials, and others. For the freeway portion of the work, participants were briefed on the causes of the safety and operational issues that occur on the freeway and were asked to think about how the freeway would work optimally with future land uses. Charette participants also contemplated how the freeway should interface with local streets—especially how multi modes of transit such as bikes, pedestrians, the Portland street car, light rail, and buses would operate as an interdependent system. As a reference place for ideas, the participants were invited to the internal city and state workshop as a starting place for envisioning how to resolve the issues on the freeway. The participants' work was guided by engineers, planners, urban designers, and architects. What emerged from the process were 70 plus design concepts of varying complexity. Given that few of the participants had background in transportation planning or design, this was no small accomplishment.

Over three weeks, the state team evaluated the concepts and ranked them according to engineering feasibility and ability to address the majority of goals and objectives as agreed to by the internal project team prior to the charrette. Concepts that did not meet the aforementioned criteria were discarded. Then, "like" designs were combined and optimised. Over several SAC meetings, the number of concepts was whittled down to five options. The remaining five scored fairly evenly on a scale of measurable and subjective criteria as agreed upon by the SAC; however, they scored well in very different categories. At this point, the direction from the SAC was for the project team to develop a hybrid concept that consisted of the most favorable elements from the remaining five freeway concepts.

The resulting design added an auxiliary lane and full shoulders to the freeway, but it discarded any additional roadway elements including braided ramps, looped exit ramps, and frontage roads. The approved design required no right of way acquisition and fit within the existing I-5 "trench" by moving the freeway embankment from a 30 degree to a 90 degree angle, thus freeing up more space for additional lanes. To accommodate the auxiliary lanes and full shoulders, several of the structures needed to be rebuilt.

Typically, new bridges are rebuilt on temporary structures and traffic diverted, until the new structures are in place. To accommodate the desires of the stakeholders and partner agencies, the team collectively agreed to rebuild the bridges on "caps" over the freeway in two locations that would allow park space, retail, or some other combination of uses to sit over the freeway—effectively providing two large contiguous parcels that connected the east and west sides of the freeway together. In addition, an agreement was made to build a bicycle and pedestrian bridge over the freeway in the southern end of the study area that would allow a much needed east/west crossing. New, additional bicycle and pedestrian route choices were planned for construction in locations with less congestion and more *people friendly* conditions. The goal for providing additional bicycle and pedestrian route choices was designed to incentivise people willing to commute via active transportation.

Finally, a new east/west bridge would be built to the north of the study area to allow new connections between the east and west sides of the freeways. This structure would not only provide a new east-west route choice over the freeway for motorised vehicles, car, bicyclists, and pedestrians, it would provide access to traditionally underutilised parcels of land located along the Willamette River waterfront west of the freeway. The new access would act to make these parcels much more attractive to potential developers, a move that is consistent with the goals of the City's 20-year Portland Plan update. In the end, the SAC approved the project by a 27 to 3 margin, the City Council unanimously approved the plan, and the Oregon Transportation Commission unanimously voted for adoption of the work into the State Highway Plan (see Figures 1 and 2).

PORTLAND PLANNING FOR THE TWENTY YEAR TIME HORIZON: CHAOS AND ORDER

With the general difficulty of seeking approval for freeway widening projects within dense, urban areas, rancor among state and city agencies related to this process, initial and significant polarisation in positions of team members, what went right given this extremely complex problem? The agency team members resigned themselves to the fact that they would not succeed while attempting to adhere to the dogmatic, rigid order typically imposed by our individual host bureaucracies. The process for all members had devolved to an extreme level of discomfort at all levels while the agencies attempted to hold tightly to fixed positions, so much so that a second mediator was called in to resolve communication issues. Through the mediation process, the team resigned themselves to the fact that the process would be uncomfortable and chaotic and resolved to dwell within the realm of possibilities that arose from the public outreach process. The team further agreed that it would attempt to interject agency order *only when drastic turns away from major agency goals were threatened.* In other words, as a team, we resigned to manage the process only when the process veered into each agency's and team's intuitive definition of chaos. The team as a whole literally agreed to dwell in the discomfiting interface between chaos and order.

The process also succeeded for a number of additional reasons, the first being a strong desire and commitment by team members from ODOT, BPS, and PDOT to the completion of concurrent plans. The city agencies required that ODOT prepare future plans for the I-5 system as the future of the N/NE Quadrant Plan required knowledge of future travel and congestion patterns as well as the location of proposed new interchanges. At the same time, ODOT saw that working with the city bureaus while updating the Portland Plan was the best opportunity to seek the city's approval on freeway design because the Portland Plan update would be incomplete without certainty on the I-5 Facility Plan.

The second strength of the process was a carefully chosen group of stakeholders to participate as members of the 30-member SAC. The committee members brought

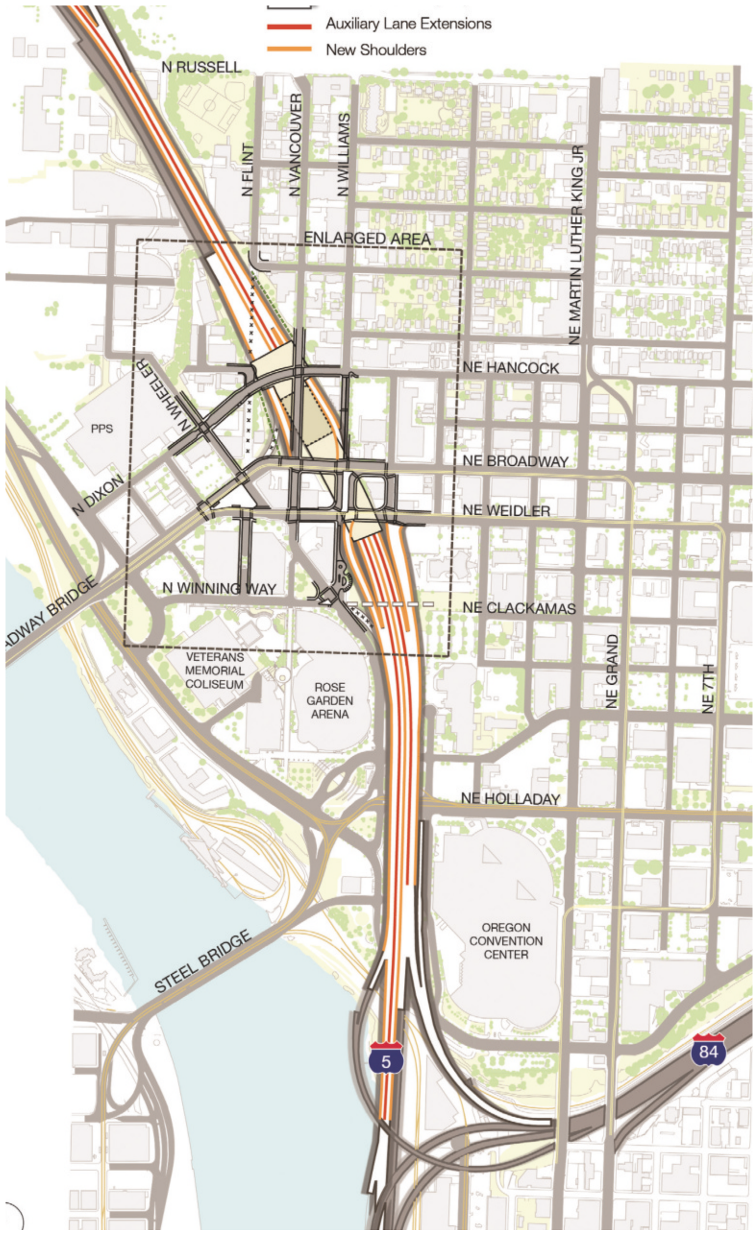

Figure 2. Overall project extent of the recommended concept.

a broad range of perspectives and extensive knowledge of the N/NE Quadrant to advise the agencies at each step of the process. Another crucial component leading to the success of the SAC process was the choice of co-chairs to lead the SAC. One member was a strong advocate for the trucking and business community and understood the larger picture of what is needed to drive economic development; the other member had extensive experience as a community leader, urban designer, consensus builder, and visionary who understood the intricacies of the elements that inspire the intense pride that Portlanders have in their community. While allowing time for vigorous debate by the SAC on issues they identified as important, the co-chairs worked to keep discussions from devolving into unproductive side conversations or long filibusters on issues outside the parameters of the SAC partnering agreement.

Management of the SAC process by the agencies, co-chairs, and mediator was also crucial to the adoption of both plans. The process included 19 SAC meetings over a two-year period as well as 14 subcommittee meetings held when more detailed stakeholder and SAC issues required side discussions. The subcommittee meetings were evenly split between those addressing transportation and land use and served to keep the main SAC meetings focused and moving. As specific decisions were made, members of the SAC attempted to form alliances to try to derail or change the direction of the process or force the SAC to revisit issues that had been voted on and seemingly resolved. The agencies spent numerous hours meeting with individual stakeholders to allow sufficient time to debate solutions to issues they identified as holding the greatest importance. The pre-SAC meetings allowed small issues to be resolved before they were raised at SAC meetings in an attempt to keep the process from losing momentum. Some of these issues were site specific; for example, one involved resolving vehicle and bicycle conflicts at an intersection in front of a historic hotel owned by a vocal stakeholder who had strong support from the bicycle and pedestrian coalition.

Other issues included concerns from two of three involved neighbourhood groups that land use and transportation changes would negatively impact their communities. Expressed concerns led to changes in the plan designed to prevent intrusion of unwanted traffic from cutting through neighbourhoods and to manage economic and circulation impacts during construction. In yet another example, the Oregon Trucking Association (OTA) was distressed that SAC rejected the inclusion of braided ramps as part of the package of freeway improvements because they feared the project would not improve freeway operations as fully as was expected at the outset. The OTA's concern led to publication of opinion pieces in the local papers as well as lobbying by the Portland Business Alliance, Central Eastside Industrial Council, and other groups to hinder SAC adoption of the I-5 Facility Plan. To resolve the issue, language was drafted into the plan with the OTA's approval. The revised language stipulated that if safety and operational concerns remained after the construction of SAC-approved freeway elements and subsequent accident and congestion monitoring, the issue of braided ramps could be reintroduced and discussed if needed.

Allowing sufficient time for public outreach and resulting discussions to run their course also increased the likelihood of plan approval and kept the process navigating along the complexity-generating *edge of chaos* instead of collapsing into either excessive chaos or rigid, dogmatic order. Over the two-year outreach period, besides the charrettes, SAC, and SAC Subcommittee meetings, the team held four community open houses, three community walks, and additional community and other stakeholder meetings with a total attendance of approximately 2,800 people. One of the lessons learned is that significant time is needed to exhaust discussions and reach agreements on issues related to an intricate and significantly chaotic process.

Media management was an important part of the process as well. When the team knew a contentious issue was to be discussed at a forum likely attended by the media, members of the team or the designated public information officers (PIOs) from the agencies met with local television, radio, and print media prior to the event to frame the issues and concerns in a favorable agency light.

Finally, an element of luck was involved with keeping the process off of the front pages of the newspapers or as the lead story on local television and radio broadcasts for much of the process. State and local politicians also provided little public intrusion into the workings of the process, and the collective character of the SAC members and their willingness to adhere to the collaboration principles all contributed to the success of the project. Some of this "luck" resulted from time and effort spent resolving individual concerns to a degree that frustrations by stakeholders did not send them scurrying to the media as a last ditch attempt to modify or derail the project.

PREPARING STUDENTS FOR THE PUBLIC AND POLITICAL PROCESS WHILE IN PLANNING SCHOOL

What can we take from these examples to inform our preparation of future planners? While time is spent in many planning programs preparing students for managing the political and public process, most students leave school ill-equipped to manage the intricacies of little more than small group dynamics. Many programs reasonably assume that there is not enough time to adequately prepare students other than through opportunities to work with municipalities through a school-based design studio. The studio results are then presented to the municipalities who often look askance or with amusement at the results because the outcomes are often too theoretical and do not reflect the political realities and other real-world constraints. For the students, the studio experience is extremely useful, though more can be done to make the classroom experience more authentic and relatable rather than relying solely on job-based mentorship postgraduation.

Planning programs should consider strategies that allow students more experience: (a) mastering the planning and political process and (b) understanding the practicalities and unpredictability of managing the stakeholder process. For instance, students need to understand that the decision to greenlight a planning project depends on many factors including lack of funding and a dearth of political and/or stakeholder support. In addition, the reality is that only a small percentage of significant planning projects are approved and built. This reality needs to be made clear to students prior to entering school or at least early on in the program for the sake of full disclosure and preparedness.

As a tool to train students in the practicalities and unpredictability of managing the stakeholder process, one suggestion is for programs to adopt a requirement for a process modeled loosely on the concept of a moot court as used by law schools to recreate appellate proceedings. Within a planning-based model, class participants could be required to take part in a simulated public process once or twice a week over a term. The instructor would take the first class or two to describe the process, pitfalls to be aware of, and tips on managing the public process in a loose style where outcomes should be focused on limited, hard parameters as would be provided by an agency or elected official. Specifically, the instructor would take the first few classes to introduce public outreach theory and process and to coach students on how to focus the process to allow outcomes to unfold based on the desires of the participants. While learning to reign in the process when it devolves into chaotic chatter and bickering, students would also learn to feel comfortable with the complexity that arises.

After introductory classes, each student would take a turn, per class period, in the role of lead planner of a mock planning project chosen by the instructor. Classmates would be provided a brief description of the mock role they will undertake in the process and their desired outcome. The instructor would then act as a moderator to guide the process while prompting the designated, lead planner when the process requires correction at each mock public process. The instructor would act as a moderator of the proceedings to keep the process on track and serve to prompt the student planner when he or she either becomes too rigid in managing the process or when the student-participant discussions devolve into useless, chaotic chatter.

The goal of the process would be to seek consensus on a smaller scale planning project within a three to four hour class period. The process would allow each student to learn to think quickly on his or her feet and, at minimum, provide an understanding of the complexity of the planning and public outreach process. It would also illustrate how to keep proceedings moving in the zone of complexity at the interface between order and chaos before entering the workforce.

CONCLUSION

When undertaking a project, the role of a planner is to develop a holistic approach to analysing problems and prescribing solutions. Adopting a holistic approach involves navigating a challenging political and public approval process. To increase the likelihood of reaching consensus and approval, the goals and objectives of public officials' desire for order must be balanced by a chaotic and complex public approval process. Skilled management of political and stakeholder expectations, choosing thoughtful participants with a broad range of desires to represent the process, and allowing enough time to exhaust and resolve issues are keys to success.

In essence, planners must anticipate the tendency of complex negotiations and collaborative projects to degenerate into excessive chaos or excessively rigid, dogmatic order when competing interests run up against one another. They must learn to view these tendencies as natural but governable in the course of their work in the urban planning profession. They must learn to back away from the minutia that can captivate participants in complex processes so they can view the big-picture dynamics of the forces pushing a project toward excessive chaos or order. In so doing, they will be more likely to help the stakeholders of a project find the productive, complexity-generating space where complex creative and critical thinking can thrive.

Finally, more emphasis should be placed on preparing planners to manage the political and public process before entering the field. One way to accomplish this is to require students to participate in mock planning processes while peers role play as stakeholders and instructors act as moderators of the proceedings.

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PETER E. PRUIM

SUBJECTIVITY, OBJECTIVITY, AND THE EDGE OF CHAOS

The concept of complexity and edge of chaos can illuminate a survey of work over the last half-century in the philosophy of mind to develop a theory of the nature of conscious mental states. In that dialectic one finds chaos that must be brought into order, order becoming restrictive, and eventually a new balance that allows for more creative theorising. The pole of chaos is identified with first-person conscious experience and the pole of order identified with objective physical theory. Uncritically accepting the character of subjective experience yields to intellectual chaos. On the other hand, dismissing the subjective character of experience as incompatible with objective science masks the inadequacy of materialist metaphysics. As a remedy, a vanguard of critics arises to promote a tense balance between the authority of the subjective and the authority of the objective. As a result, the essential nature of subjective and objective can be more clearly articulated and the problem of mind more deeply appreciated.

Complexity theory and its model of equilibrium between chaos and order bear many similarities to models of theory justification in contemporary epistemology. Effective theorising requires that both data and established theory be treated seriously, yet neither is regarded as an ultimate authority. Theory must answer to observation, yet an individual observation may be dismissed as illusion. However, if theory overrules observations too cavalierly, it becomes sealed off from falsification and so degenerates into a dogma and faith. Hence, it is necessary to maintain a skillful balance of the claims from observation and from theory as an example of equilibrium and the edge of chaos

This model of theory-making can illuminate a survey of work over the last half-century in the philosophy of mind to develop a theory of the nature of conscious mental states. In that story one finds chaos that must be brought into order, order becoming restrictive, and eventually a new balance that allows for more creative theorising. To see this, let the pole of chaos be identified with first-person conscious experience and the pole of order be identified with objective physical theory.

CHAOS—SUBJECTIVE EXPERIENCE AS INDUBITABLE

“Cogito, ergo sum – I think, therefore, I am” (Descartes, as cited in Lafleur, 1956, p. 21). That this is the most widely recognised sentence from Descartes’ philosophical work is most apt, for it captures the fundamental role played in his philosophy by

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 141–157.

first-person thought and experience. In the face of radical doubt, Descartes meditates on the character his first-person experiences, accepting their character at face value and finding in them the ultimate foundation for any claims to knowledge. It is from meditation on the character of conscious thought and conscious experience that he produces arguments for his metaphysical account of reality as a dualism of mind and matter.

A brief sketch of Descartes' arguments from his *Meditations* will reveal the central role played by his accepting as authoritative the content of his subjective experience. He seeks to find certainty. His method is to put aside whatever is susceptible to the least possible doubt. Everything falls to the wayside until he begins to think about thinking. In a moment of clarity he grasps that it makes no sense to doubt that he is thinking, since to doubt is to think. Thus, he knows he thinks, and thus he knows he exists, at least as a thing that thinks. But what is a thing that thinks? Descartes answers with what seems clear about his thoughts and imaginings. A thing that thinks is "a thing that doubts, understands, conceives, affirms, denies, wills, refuses, which also imagines and feels" (Descartes, as cited in Cottingham, 1996, p. 19). Is that thing a body? Descartes notes he cannot conceive of mind being without those powers, but the same cannot be said of body; he can conceive of bodies being without such powers. Of bodies he cannot conceive of them being without spatial extension, but the same cannot be said of mind; he can conceive of a thinking mind without it taking up space. On the basis of these differences in what he can conceive clearly, Descartes concludes that a mind and a body are two distinct objects.

Descartes develops his dualism further, again by attending to the contents of his conscious experience. It seems obvious to him that a mind's activity occurs in time but not in space, and so mind has a life span but not a shape or size or weight. In contrast, it seems obvious that a body/brain exists in both time and space; a body/brain has shape, size, position, and other properties that may attach to a material object. Hence, mind and body are not merely numerically distinct but fundamentally distinct in nature.

Nevertheless, Descartes maintains that mind and body are able to causally interact despite having radically different natures. His arguments rest, once again, on the character of his first-person experience. When he *decides* to walk, his *legs* respond. The cause of his legs' motion seems to be his conscious decision. If Descartes' *body loses water*, he will *experience pangs* of thirst.

Descartes' picture of mind and body as an interactive dualism became the standard view, so much so that Ryle (1949) in the opening of *The Concept of Mind* dubbed it "the Official Doctrine" (p. 11). Nevertheless, the doctrine proved to be an intellectual chaos. It splits reality into two fundamental realms with radically different natures, differences that prove to be incompatible and irreconcilable. Arrays of problems emerge – scientific, conceptual, and epistemological.

1. The proposed causal interaction between immaterial mind and brain cannot be reconciled with physical laws. In every physical event, certain physical quantities

are conserved. For instance, the total momentum of all the physical masses involved is, by law, the same before and after any physical change. Therefore, if something non-material, having no mass or momentum or mass-energy, were to interact with a physical mass—speeding it up or changing its direction—there would be greater momentum in the system than there was before. So, the physical law of conservation of momentum would be violated if an immaterial mind were to causally affect something in the physical universe. It is not an overstatement to say that each mental-physical interaction would be *supernatural* and a *miracle,* violating the basic principles governing all of physical reality.

2. Mind-brain interaction also raises a conceptual difficulty. For one event to cause another requires the two to be contiguous in time and space; there is no action at a distance. (Contemporary quantum physics includes the notion of entangled particles whose states are dependent even when separated by great distance. However, even this is not a case of action at a distance since particles are entangled only if they interacted locally in the past. This feature appears in the initial definition of entanglement given by Schrödinger, 1935.) However, since Cartesian minds are said to be non-material precisely by not being in space, a Cartesian mind is never being contiguous to the brain. So mind-brain interaction would be a conceptual impossibility.
3. Cartesian dualism renders mind unavailable for scientific investigation. For, while the physical is public, the Cartesian mind is private. Physical events are open to public observation and study, and observers may study the working of the brain. But in doing so, they are not observing anything immaterial; hence, in Descartes' view, they are not observing minds. Our brains can be investigated by a community of scientists, but each mind is the private province of one subject.

In sum, Cartesian interactive dualism would require special dispensation from the laws of physics and the requirements of causation and blind faith in the presence of consciousness in any creature other than me. This characterisation of mental events renders them chaotic in the sense of being unpredictable and unintelligible. For example, how an act of will might produce bodily movement is beyond investigation; for the exercise of will is a private episode inaccessible to investigators, the effect of will on the body is unconstrained by physical law, and the notion of the will's having an influence without being a causal event in space is at odds with the very meaning of cause in the sciences. In order to render mind intelligible, it would seem that the concept of mind must be recast so as to be amenable to the methods of public investigation and constrained by the laws of nature. This was the project of the materialists.

RESTRICTIVE ORDER—MATERIALIST DOGMA

Many philosophers served as critics of Descartes' metaphysics of mind. But perhaps no critic has more directly attacked Descartes' reliance on private introspection than Ludwig Wittgenstein. He argues strenuously against the viewing of cognitive activity as *inner* activity accessible only to a subject via introspection. What drove him to this issue were questions about the nature of mathematics, logic, and language in general. Philosophers since antiquity regarded the use of mathematical symbols and language as outward physical signs for inner mental activity. This tradition is captured in the quotation from St. Augustine that Wittgenstein (1953) nailed to the opening page of his *Philosophical Investigations,* his strenuous critique of that tradition. The fulcrum of that critique is what has come to be known as *the private language argument*—a reductio of the notion of a language spoken and understood by just one person. If the reductio is successful, then the very idea of essentially private states is rendered absurd.

If the rejection of Cartesian Dualism was progress, it also had a down side in the form of a new dogma. The influence of the private language argument was so great that a theorist would be taken seriously only if he or she restricted analyses to public, objective notions. Dualism was replaced by metaphysical materialism as a dominating dogma among Analytic Philosophers of the English-speaking world. Materialists simply assumed that mental activity had to be physical activity in some sense; the task for philosophy of mind was to make clear just how and in what sense this is the case.

Did the materialist dogma or paradigm stifle creativity? A survey of the general types of materialist accounts reveals their shortcomings. Materialist accounts that arose after Wittgenstein include behaviourism, the mind-brain identity theory, functionalism, and eliminativism.

Under the influence of Wittgenstein, Ryle developed a behaviourist account of the mental in his 1949 work, *The Concept of Mind.* In the opening chapter, "Descartes' Myth," Ryle portrayed Cartesian immaterial mind as an absurdity; he dubbed it *the ghost in the machine*. Like Wittgenstein, Ryle strenuously argued that mental terms like *thinking* do not refer to an inner, private activity. Ryle's distinct contribution was his diagnosis of how dualists had come to think of the mental as private. Ryle accused them of a making a particular mistake about mental language: a category error. Dualists mistakenly regarded mental terms as belonging to the same logical category as terms describing physical events and as a result postulated the existence of non-physical events.

What is the error attributed to the dualist? Consider a simple ascription of mental trait. What is the difference between a person raising an arm just to stretch and another person raising an arm in order to ask a question? There might not be any physical difference supposing both arms move in the same way. What is different is the presence or absence of an intention. One person raised an arm with no intention, but the other raised an arm intentionally. What does this difference amount to? Ryle argued that it is at this point the dualist makes a mistake. The dualist treats *she raised her arm intentionally* and *she raised her arm slowly* as being of the same logic type – stating what event is occurring. Suppose our two people each raises an arm, each raises it slowly, but only one raises the arm intentionally (to ask a question).

The physical occurrences in the two bodies are the same; so, if *raised intentionally* is taken to be pointing to an occurrence, it would have to be some nonphysical occurrence.

Ryle countered by saying the dualist is wrong to treat *raised slowly* and *raised intentionally* as phrases of the same logical type, as stating what is occurring. Rather, *raised intentionally* attributes to the person a set of behavioural dispositions. What is different about raising an arm intentionally rather than just to stretch is not a difference in *what events occur*, for they are the same in both cases; instead, the difference is in *the dispositions* the two people have. What is different is what each would do in other circumstances. For instance, if the lecture had been just as tedious but on a different topic, the first person would still raise the arm but the second person would not. We describe someone's behaviour as purposeful or skill, according to Ryle (1949), not by going behind the behaviour, but by going beyond it.

It would be hard to imagine an account of the mental that expunges the notion of inner private episodes more than Ryle's behaviourism. He jettisoned not only the Cartesian notion of private immaterial states of consciousness but also any reference to physically inner brain activity. On his account, to say that person S believes the ice is thin is to attribute to S a set of bodily behaviours that would be undertaken in various circumstances. For instance, S would refuse to venture on to the ice if invited; S would say the word *yes* in response to hearing the words: "Is the ice thin now?" Note, nowhere in the analysis is there a mention of what might be occurring somewhere inside, be it inside brain or mind.

Ryle's behavioural analysis of mental trait terms appears to meet the constraints of materialism, since the analysis involves refers only to body behaviour. However, critics charged that the analysis does not successfully capture the meaning of our mental ascriptions. One difficulty is how quickly the analysis grows unwieldy – believing the ice is thin entails specific responses to a host of possible conditions. But the more devastating problem is the analysis runs into circularity. Return to our example. The analysis of *S believes the ice is thin* cannot be as simple as S, if asked about the ice, will utter the words: "The ice is thin." For S can be expected to exhibit such behaviour only if certain other mental traits are also present, such as the desire to be cooperative and truthful. But what does it mean to say S desires to be cooperative and truthful? The behaviourist analysis of that would include: S will utter, if asked, the words: "The ice is thin." provided S believes that the ice is thin. The underlined clause renders the behaviourist analysis of *S believes the ice is thin* tightly circular.

In the face of these criticisms, many materialists concede that sentences ascribing mental traits do not have the same meaning as sentences using only behavioural language. However, materialists endeavor to show that despite the difference in meaning, mental and physical terms nevertheless refer to the same entity – a physical brain. It would be an empirical discovery by neuroscientists that mental terms such as *thinking* and *feeling* do in fact refer to the same entities as do such physical terms as *neuron synapsing* and *hormone release*. Put simply, science would show the mind to be none other than the brain. Advocates of the identity theory, such as Smart (1949), drew inspiration from other examples of reductive identities in science. The terms *water* and *hydrogen dioxide* do not have the same meaning, yet empirical science discovered that these terms refer to the same entity.

But how is the identity to be established? Neuroscientists can use MRIs to show types of brain states are correlated with ascriptions of mental states. But correlation is not yet identification. The identity theorists do not want to say just that, for instance, my lethargy and feeling of hopelessness are correlated with depleted sugar levels at certain brain sites but that the feeling just is the low sugar level, in the same sense that water is just H_2O. Not only is it difficult to argue for the move from correlation to reduction, one might object that the very suggestion seems preposterous. How could anyone fail to distinguish a bit of unsugary brain syrup from the feelings of ennui? But such objections are easily deflected by a general refusal to treat any first-person experience reports seriously. The influence of Wittgenstein empowered the identity theorists to chastise their critics for being unscientific and overly impressed with pre-scientific terms such as *feeling*s that are holdovers in our language from a pre-scientific age. The identity theory eventually fell out of favor, but this was not due to the audaciousness of identifying feelings or images with configurations of tissue. The dogma of materialism sufficed to hold off such protests. Rather, it was a theoretical infelicity, an objectionable chauvinism that would result. Different species seem to share certain mental states like fear, even though they do not share the same neural structures. It seems chauvinistic to claim that only humans can fear because only they possess their peculiar brain configuration.

The worry about chauvinism was taken away by the move to functionalism. Function, rather than physiological structure, became the materialists' most promising approach to understand mental states as part of the physical world. Since a function can be performed by a number of different structures, understanding thinking or fearing as functions offered a solution to the chauvinism that plagued the identity theory. Creatures with different types of brain structures could nevertheless share the same mental traits – if the different structures performed the same function. The concept of function brings with it the concept of malfunction; and the latter promised to provide a way to understand such pairs as seeing and illusion, knowledge and false believing. Furthermore, if at the core of all mental states is some notion of representation, the functionalist can be encouraged by the functional nature of representation. Something qualifies as a sensor or a gauge in virtue of its function – of what it can do. And, happily for the materialist, these functions are observed to be performed by physical systems, both natural and man-made.

Philosophers developed many interesting accounts of mental states in terms of functions that seem to be able to be performed by purely physical systems. An excellent example of this approach is a functionalist theory of information, representation, sensation, and cognition developed by Dretske (1995) in *Naturalizing the Mind.*

However, as with the other materialist accounts, considerations from first-person consciousness raise difficulties. One version of functionalism is computationalism. Computationalism proposes that thinking consists in being able to correctly manipulate the symbols. Correct manipulation means: if confronted with symbol, the system responds with another symbol that is the appropriate one, given what the symbols mean. For instance, given the symbol: *2+3=?* The system gives out the symbol *5*. Given the symbol: *What team in the National League plays in Chicago?* The system gives out the symbol, the word *Cubs*.

A famous counter-example to computationalism is given by Searle (1980) in his *Minds, Brains, and Programs*. His widely discussed *puzzle of the Chinese room* describes a system that meets the computationalist specifications for understanding Chinese – issuing the correct output Chinese characters—but without understanding anything about Chinese. This is possible if there is a correlation between a symbol's shape and what the symbol means. A machine can be programmed to respond to input shapes with the correct output shapes without understanding anything about the meaning associated with the symbols. The machine will behave *as if* it were responding to the meaning of the symbol, though it is not. Genuinely understanding a sentence is responding to the meaning. Once again, the criticism of the materialsts' account of the mental appeals to a feature of the first-person perspective; in this case, it is understanding a symbol's meaning.

The most extreme case of yielding to the dogma of materialism was eliminativism. Like the identity theorists, eliminativists drew inspiration from the history of science. They focused not on examples of theoretical reductive identification, but of theoretical elimination. In the former, what were thought to be two are shown to be one. For instance, lightning is shown to be a discharge of electricity. In the latter, what was thought to exist is shown to be nothing at all. There are no demons possessing human victims; those said to be possessed are suffering from an entirely other affliction. Note in this case, it is not that sciences shows what demons are, but that we were wrong to think demons exist. Another frequently cited example of theoretical elimination comes from the history of chemistry. An early theory of combustion proposed the existence of a caloric fluid, phlogiston, given off as material burns. This theory was replaced by the theory of molecular combination involving oxygen. It is not that science showed that phlogiston was the same thing as oxygen; rather, science eliminated the notion of a caloric fluid altogether for a better theory. In an analogous way, the eliminativists hoped to discard the very notion of the character of first-person conscious experience for a better theory of human behaviour, a theory given in terms of sense organs, brains, hormones, and muscles. Among the most prominent advocates of this approach is Dennett (1988) who writes:

> Look at a glass of milk at sunset; *the way it looks to you*—the particular, personal, subjective visual quality of the glass of milk is the *quale* of your visual experience at the moment.…At first blush it would be hard to imagine

> a more quixotic quest than trying to convince people that there are no such properties as qualia…. But I am not kidding.

My claim, then, is not just that the various technical or theoretical concepts of qualia are vague or equivocal, but that the source concept, the 'pretheoretical' notion of which the former are presumed to be refinements, is so thoroughly confused that even if we undertook to salvage some 'lowest common denominator from the theoreticians' proposals, any acceptable version would have to be so radically unlike the ill-formed notions that are commonly appealed to that it would be tactically obtuse—not to say Pickwickian—to cling to the term. Far better, tactically, to declare that there simply are no qualia at all. (p. 42)

If successful, eliminativists such as Dennett would exorcise the ghost from the machine as well as prevent it from coming back to haunt them with objections. For, in the context of such an approach, to raise points about the first-person character of experience is to discredit oneself as a serious participant. Dennett (1988) was upfront about his intention in this regard:

> I want to shift the burden of proof, so that anyone who wants to appeal to private, subjective properties has to prove first that in so doing they are *not* making a mistake. Today, no biologist would dream of supposing that it was quite all right to appeal to some innocent concept of *elan vital*. I want to make it just as uncomfortable for anyone to talk of qualia—or 'raw feels' or 'phenomenal properties' or 'subjective and intrinsic properties' or 'the qualitative character' of experience—with the standard presumption that they, and everyone else, knows what on earth they are talking about. (p. 42)

Dennett carried out his program in his 1991 volume *Consciousness Explained.* The book was enormously influential and widely critiqued in the discipline.

EQUILIBRIUM – OBJECTIVE SCIENCE AND SUBJECTIVITY

Eliminativists such as Dennett believe themselves to be champions of science and serious intellect, but their dogmatic embrace of materialism stifles an entire avenue for criticism. Raising the issue of subjective consciousness becomes akin to uttering "Skull and Bones" at Yale. But such an environment makes it impossible for our theories of conscious state to capture the complete truth. In order to move into a state of equilibrium between the authority of objective physical science and the data of consciousness, the stigma against the latter would have to be removed. To emerge from the stasis would require skillful arguments to rehabilitate the notion of conscious experience as a genuine feature of reality and as a legitimate subject for investigation and as legitimate evidence to measure the adequacy of theories.

It was a very few who attempted to rehabilitate first person subjective experience as a desideratum for theories of mind. Perhaps the most important figure in that vanguard is Nagel (1994). He chastised eliminativists as poor practitioners of science. He flatly insisted that the phenomenal features of conscious life are a most obvious and unavoidable category of data:

> To regard it as unreal because it cannot be accounted for by the methods of current physical research is to get things backwards. The data are not determined by our methods; rather the adequacy of our methods is determined by whether they can account for the data….To admit to reality only what can be understood by current methods is a sure recipe for stagnation. (p. 67)

In "What is it like to be a bat?" his widely anthologised essay, Nagel (1979) proposed the feature by which conscious states are distinguished from the non-conscious is the presence of a *point a view*. For instance, for a bat to be in pain is different from its being made of proteins in that "there is something it is like to be [in pain] – something *for* the organism" (p. 166). In contrast, a bat's being composed of proteins is not a conscious state; a dead bat is still composed of proteins. By treating point of view as a defining quality of consciousness, Nagel is able to reveal the implausibility of eliminativist materialism –whose central tenet is to remove from accounts of the mental all talk of first-person concepts. In the same breath, Nagel is able to reveal the incompleteness of the other forms of materialism. While the details of brain structure, brain functions, or patterns of stimulus-response behaviour are part of the story of consciousness, they leave out an essential feature –the point of view associated with mental states. Moreover, to leave out this point of view is to skip the hard work. For this feature is what makes consciousness uniquely puzzling: how a cinematic whirl of images, sounds, and feelings emerge from merely the activity of nerve cells.

A second group of theorists took Nagel's puzzle seriously. Two books appeared in the same year: Searle's (1992) *The Rediscovery of Consciousness* and Flanagan's (1992) *Consciousness Reconsidered*. Flanagan dubbed Nagel's puzzle "the hard problem" of consciousness. He devoted the first chapters of his book to showing why the eliminativists' arguments do not succeed at dismissing this problem of consciousness.

Flanagan's first move was to point out disanalogies between the cases of ghosts and caloric fluid and consciousness. We can make sense of the claim that there are no ghosts, only shadows that seem like ghosts. But, can we analogously maintain that there are only brain states and no pains, that brains sometimes seem to be pains and people misinterpret certain brain events as pains? No; for, to seem like a pain is to be a pain. Hence, there is no sense to the idea of seeming to be a pain but really not being one, as there is to the notion of seeming to be a ghost but really not being one.

After pointing out the disanalogies, Flanagan pointed to an equivocation in many of the eliminativists' manifestos between eliminating the idea of consciousness and simply revising its traditional characterisation. The former, genuinely eliminative thesis Flanagan represented with this passage from Dennett (1988):

> This special status for these presumed properties [properties of subjective states] has a long and eminent tradition. I believe it was Einstein who once advised us that science could not give us the taste of the soup. Could such a wise man have been wrong? Yes, if he is taken to have been trying to remind us of the qualia that hide forever from objective science in the subjective inner sancta of our minds. There are no such things. (p.42)

Flanagan emphasised that this brand of eliminativism is implausible and must not be confused with more modest and plausible views–those that retain the notion of consciousness but eliminate commonly held claims about it. As an example, Flanagan highlighted the following from the eliminativist Churchland's (1986) *Neurophilosophy*:

> In a previous publication (1983) I argued that consciousness, as it is circumscribed in folk psychology, probably is not a natural kind, in much the same way that impetus is not a natural kind. Nor, for example, do the categories 'gem' and 'dirt' delimit natural kinds. That is to say, *something* is going on all right, but it is doubtful that the generalizations and categories of fold psychology either do justice to that phenomenon or carve nature at her joints. (p. 321)

This position proposes merely to get rid of some of the claims made in folk psychology, that it may be mistaken about consciousness being a single unified state. More importantly, for Churchland to concede that "*something* is going on" suffices to readmit conscious subjective states into the picture.

AT THE EDGE OF CHAOS - CREATIVITY

Once first person subjective experience is restored as a desideratum for theories of mind, there arise creative new issues and accounts.

New Methodology

Flanagan (1992) devoted the remainder of his book advocating and detailing a more open but still scientifically sound approach to the study of mind. The methods of science if properly employed will produce *naturalised theory of mind*. The key is to balance considerations of the material – physiological, neurological – with first person phenomenal consciousness. Flanagan built on a suggestion from Churchland herself, in order to draw attention to the compatibility of his approach with the interests of empirical science:

> Churchland promotes the idea of concept transformation. . . . We need to study the 'neurophysiological differences between conscious and non-conscious states. We need to work out views on the nature of attention, vision, and dreams by *yoking descriptions of attention, vision, dreams and so on, framed*

> *in phenomenological and functional terms, to credible brain research'* (1986, 362, my italics). What consciousness is will be understood only after such coevolutionary give-and-take among different levels of description and among adjacent sciences has been given time to wend its way toward a thick and rich description of the phenomena we now have a very incomplete sense of. This is straightforward advocacy of the natural method I recommended. (pp. 26-7)

The fruitfulness of such an approach can be seen in contemporary research on blind sight and Anton's Syndrome. In the former cases, individuals report experiencing blindness, yet are able to negotiate around objects in the environment. Anton's Syndrome is the reverse: individuals report having visual experience but are unable to negotiate objects. Researchers take seriously reports of first-person experience but employ objective methods to determine just what cognitive ability is actually present. The cognitive ability does not match the first-person reports, so the pre-theoretic conception of consciousness as transparent and incorrigible is abandoned, but not the concept of qualitative consciousness *tout court*.

New Concepts and Quests

Nagel's subsequent work is an example of creativity at the edge of chaos. He represents work in equilibrium between the data of conscious experience and the contributions of empirical scientific methods. On the one hand, he makes use of aspects of conscious experience as a tool to criticise the materialists' accounts and thereby is able to show why the latter do not capture the complete truth about consciousness. On the other hand, he respects their achievements as providing at least part of the truth, and so he is able to use achievements in materialist accounts as a tool to render more clearly the non-material, first-person perspectival aspect of consciousness.

Working in this fashion Nagel produces work that is most creative. By bringing together the data of conscious experience and the most mature materialist account of the mental, he not only (a) shows the shortcoming of the materialist account, but (b) launches into an explanation of why objective investigation must inevitably be incomplete. Furthermore, doing so enables him (c) to articulate clearly the essential difference between subjective and objective: it is not the difference between unreal vs. real, but between having a point of view vs. removing particular perspective.

The concepts of subjective vs. objective are explored at length by Nagel (1986) in *The View from Nowhere*. The title expresses his characterisation of objectivity as representing reality as it is in itself. How things are in themselves is how things are independent of whether and how they are presented to minds. For, to be in mind means to be the object of some point of view and particular mode of experiencing. For instance, air molecules oscillate (soundlessly) but independent activity will produce in human beings an auditory experience, a sound, and in other types of minds, like canines, another sort of auditory experience. An objective account aims to remove the features that belong only to the point of view, the type of mind, the experiencing. The attempt is made to "view the world not from a place within it, or from the vantage point of a special type of life and awareness, but from nowhere in particular and no form of life at all" (Nagel, 1979, p. 208). Modern science has done this with astounding success. "The result is an understanding of objective physical reality almost unrecognisably different from the familiar world of…experiences" (Nagel, 1994, p. 66). Science reveals that, for example, what seems to be a single solid stationary object is, in itself, a composite of vibrating atoms, that are themselves mostly empty space.

With this characterisation of scientific investigation and objectivity, Nagel (1994) is able to articulate why the methods of science in principle cannot yield an account of consciousness that is complete:

> It was a condition of this remarkable advance that subjective appearances of things be excluded from what had to be explained and described by physical theories….it follows inexorably from this strategy that the same methods of objective physical understanding cannot be successfully applied to the subjective contents of the mind themselves. The method can be used on the body, including its central nervous system, and on the relation neural activity to observable behavioural functioning, because these are all aspects of objective physical reality. But, for the subjective qualities of experience themselves, we need a different form of understanding. We cannot hope to understand them completely as an aspect of objective physical reality because the concept of objective physical reality depends on excluding them from what has to be understood. They are excluded, because they are tied to a species-specific point of view that the objectivity of physical science requires us to leave behind. (p. 66)

When science applies its methods to study our conscious mental states, its objective account includes details about the functional role of neural states, causal feedback loops between objects sensory organs and muscle responses, public linguistic behaviour, and so forth. This is a valuable advance. But, warns Nagel (1994), this must not be regarded as a complete accounting.

> In addition to their functional role in the explanation of behaviour and their concrete physiological basis, conscious mental states have characteristics of a third type, familiar to us all, namely their subjective experiential quality: how they are or how they appear or feel from the point of view of their subjects. (p. 64)

Recognising the limitations of objective methods, while embracing what they do achieve, leads Nagel (1994) to new questions.

> If we are to take the next great step, to a truly theoretical understanding of the mental, we must proceed by regarding this limitation as a challenge to develop

> a new form of understanding appropriate to a subject whose exclusion from physical science was essential to its progress….This may be unattainable, but without it we cannot have a general cosmology. (p. 68)

By restoring the legitimacy to pre-theoretic experience and balancing it properly with the merits of physical science, hubris is replaced by humility that may or may not lead us to a complete understanding but certainly brings a deeper appreciation of a mystery.

FINAL REFLECTIONS

The concepts of chaos, order, and equilibrium can be applied to the recent history of philosophy of mind. During equilibrium periods, when respect was given to both objective science and subjective experience, new and more complex theories emerged. What is the significance of this? Is it merely a descriptive point about the history of ideas, that periods of equilibrium are periods of creativity, or is there a normative lesson? That is, should equilibrium states be preferred, preferred in the sense that their new, more complex theories are more justified and more likely to be true?

A case can be made for the normative thesis. Our survey of developing theories of mental states can be taken as one example of the general practice of developing theories about the nature of things. In order to construct theories that aim toward being true, a balance must be struck between the authority of data and the authority of confirmed theory. A productive (that is, truth-conducing) balance of data and theory seems to have the same structure as the balance of chaos and order conducive to complexity. Consider, first, the role and character of data. For our theories to be true, the world must have a say in their construction. The world has its say by producing experiences. But the authority of experience is not absolute. Experience can be misleading. Indeed, experience is ever changing, even when the underlying reality is stable. For example, a cup seems to change its size and shape as views change their vantage point, even though the cup itself is not changing so. Hence, appearance cannot be taken at face value. Some are regarded as veridical, others dismissed as illusions. Next, consider the role of theory in that process. To experiences we bring theories of what is the true nature of the source of experiences. For example, it is a theoretical claim the ever-changing appearances of a cup are produced by an unchanging cup. This theory explains why the appearances change in the surprisingly coherent manner that they do, in contrast to the incoherent experience of mere dreaming. Theories offer explanation for what otherwise would be an unconnected, unintelligible parade of sensations.

So, experience is to be the justification for theory, but theory may at times overturn the testimony of experience. Hence, neither has absolute authority. Consideration of data must be balanced with consideration of theoretical successes. The chaos of appearance must be balanced against the stability (order) of successful theory. Only by acknowledging both but giving absolute authority to neither can our account of reality approach being true. Only theory construction that occurs at the edge of chaos, between present experience and confirmed theory, is likely to approach the truth of things.

Such a non-foundationalist epistemology has been argued for by a great many philosophers in the 20th Century. Much of this work was in reaction to logical positivism. Critics of positivism, such as Quine (1951), portrayed it as overestimating the capacity of experience to adjudicate and underestimating the role of confirmed theory in assessing the testimony of the senses.

The model of theory construction and justification as occurring at the edge of chaos might be useful for disabusing college students of misperceptions about the nature, practice, and history of the sciences. Students can all too easily fall prey to a triumphalist view of science. Advances in theory are thought to result simply from having new data and superior intellectual integrity. A related misperception is that the views in science are ever-changing and past views play no role. Not only does such a view undervalue past work, but ironically, undervalues present work as well, since it can be regarded as just as transient. To correct these misperceptions, students should be made to appreciate that judgment is required to balance observation with past theoretical success. For example, Albert Einstein was willing to accept relativity, given the data, but not quantum mechanics. It was a loyalty to theory that prompted his remark about God not playing dice with the universe. By bringing out the role of judgment in balancing the testimony of experience and theory, students may be made to see empirical science as a matter of *critical thinking,* rather than as mere data collection or experimental proofs.

An exercise that might bring to light the interplay of subjective certainty and theoretical coherence would be to have students work out a difficult crossword puzzle. Let individual entries represent particular observations, while the intersection of entries represents theoretical coherence. To complete the crossword, one must give authority both to the answers to individual questions and to how the many answers fit together. But neither consideration is absolute. In some cases, difficulties with fit should prompt change in an individual answer – even if it seems so right. In other cases, difficulty in accepting an individual answer should prompt revision in an otherwise beautiful intersection of answers. Seeing the fruitfulness of both sorts of revisions may give students an appreciation of the methods and history of science and of the real-world need for critical thinking.

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SECTION 4

CREATIVE EDUCATIONAL FRAMEWORKS AND INITIATIVES

DON AMBROSE

SEEKING CHAOTIC ORDER: THE CLASSROOM AS A COMPLEX ADAPTIVE SYSTEM

The vibrant, interdisciplinary science of complexity is illuminating the tendency of complex adaptive systems to oscillate along a continuum from chaos to order, occasionally finding a complexity-generating space somewhere between the two extremes. Awareness of the continuum can enable educators to understand more clearly their own career development, the intricacies of students' learning processes, and the erroneous nature of many school reform initiatives. The continuum also can help educators in the development, refinement, and application of instructional models and strategies that are conducive to complex, higher-order thinking.

In an ancient Greek myth, sailors attempting to travel through the straits of Messina had to pass between a rock and highly turbulent water. Those who steered away from the rock were drawn into the churning water. Those who avoided the turbulence were dashed against the rock. Successful passage through the straits demanded artful navigation between the two obstacles.

There is mounting evidence that complex systems in nature must navigate between similar obstacles: the rock of excessive stasis and the turbulence of extreme disorder. Too much order or too much chaos over the long term inhibits the development of a complex system. But if the system discovers the most promising position between these two extremes it can develop to ever-higher levels of complexity.

A teacher and her or his class also must navigate between these extremes. Imagine a network of individuals constantly acting upon and reacting to one another, the environment of each member of the network a product of these interactions. No single agent in the network controls everything. Coherent behaviour arises from the competitive and cooperative interactions among these individuals. The network or system as a whole periodically reorganises as it gains experience. It will not stay in steady equilibrium although there are periods of relative calm broken by periods of intense growth and restructuring. The system perpetually explores, groping its way through a region of endless possibilities, always looking for improvement but never achieving perfection. The individual elements in the system sometimes transcend themselves and acquire properties or levels of development they might never have achieved on their own. These are some of the properties of complex adaptive systems. Such systems are the focus of study in the emerging science of complexity (see Anteneodo & da Luz, 2010; Axelrod 1997; Bleakley, 2010; Boedecker, Obst, Lizier, Mayer, & Asada, 2012; Chen, 2010; Fontdevila, Opazo, & White, 2011; Gershenson, 2012; Holland 1998; Kauffman 1995; Kelso, 1995; Lizier, 2012; Mazzocchi, 2012;

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 159–183.

Miller & Page, 2007; Morowitz, 2004; Richards, 2001; Schneider & Somers, 2006; Thompson, 2007; Watts 1999). A typical classroom in a typical school exhibits many if not all of these properties. By studying the nature of complex, adaptive systems, educators may gain some insights that will enable them to vitalise thought processes and leadership behaviours in their classrooms and schools.

The researchers and theorists who study the nature of complex systems come from diverse disciplines. Although complexity theory and chaos theory (a precursor of complexity theory) emerged from physics and chemistry (Prigogine & Stengers, 1984), some investigators have found interesting parallels that more directly relate to human thought and behaviour. For example, economists and political scientists are studying complex adaptive systems in their fields in attempts to address the inability of classical theories to explain the turbulent and irrational nature of many economic and political phenomena (Axelrod 1997; Balzacq & Jervis, 2004; Jervis 1997, 2012; Miller & Page, 2007). Even closer to the heart of human experience, Kelso (1995) Richards (2001), Spivey (2008), Sterling (1992), and Thompson (2007) developed conceptions of cognition based on interpretations of the human brain as a complex, nonlinear dynamic system. These theories imply that the behaviour of complex adaptive systems applies to the field of education because cognition and creativity are important aspects of classroom experience.

As mentioned earlier in this book, researchers and theorists have been applying insights from complexity theory to their investigations of phenomena in multiple academic disciplines. Some researchers have applied complexity theory and chaos theory to educational issues. For instance, some investigators have illuminated educational leadership and school improvement issues through concepts borrowed from chaos theory and complexity theory (e.g., Beabout, 2012; Blair, 1993; Garmston & Wellman, 1995; Griffiths, 1997; Gunter, 1995; Hunter, 1996; Moore, 1998; Morrison, 2002, 2010; Scheerens, 1997; Wertheimer & Zinga, 1998). Other scholars have used chaos or complexity theory to better understand educational philosophy (Mason, 2008; Morrison, 2008), learning disabilities (Cherkes-Julkowski, 1996; Guess & Sailor, 1993), multicultural issues (Polite, 1994), language learning (Larsen-Freeman 1997), motivation (Dowson, Cunneen, & Irwin, 1999; Rea, 2003), gifted education (Dai & Renzulli, 2008), and various other aspects of curriculum and instruction (see Doll, 1989, 2012; Goff, 1998; Harjunen, 2011; Levonen & Tukiainen, 1996; McAndrew 1997; Stanford, 1996; Tennyson & Nielson, 1998).

These avenues of research have not been without detractors. Some time ago, Hunter (1996) cautioned that researchers cannot substantiate the applicability of chaos theory to human behaviour on the collective scale, yet recommended its use to inspire new thinking in educational administration. In a similar argument, Benson and Hunter (1993) contended that it is inappropriate to apply chaos theory to education because the basic concepts and research methods that were developed within the physical sciences, are not suited to human behaviour.

Notwithstanding these criticisms, in recent years the study of complexity has become even more vibrant in many disciplines and many phenomena described by complexity theorists seem to apply to education. Ask veteran teachers to consider the properties of complex adaptive systems and they are likely to recall their first few years in the profession. Their early, idealistic attempts to predict and control the learning and behaviour of 25 rambunctious young individuals in their first classrooms often went awry. Because the emerging science of complexity is illuminating the nature of some behaviours, it provides an interesting perspective from which to broadly view education today. Some characteristics of complex adaptive systems promise to shed light on the ways in which our students, teachers, classrooms, and schools function. Most promising of these characteristics is the tendency for complex systems to oscillate along a continuum from chaos to order, occasionally finding a transient, complexity-generating space somewhere between the two extremes.

THE NATURE OF COMPLEX ADAPTIVE SYSTEMS: LAKES OF CHAOS AND ISLANDS OF ORDER

A complex adaptive system operates in peculiar ways. At times it will freeze into a state of static order. But it is an open system, so the ongoing input of stimuli from its environmental context eventually overrides the pattern of order and the system falls into chaotic disequilibrium. After a period of turbulence, the system again settles into a state of order, often at a higher level of developmental complexity (Kauffman, 1995). In essence, the system can be thought of as oscillating along a chaos-order continuum.

The behaviour of freezing fluid further illustrates the nature of complex adaptive systems. Just above the freezing point, most molecules in a fluid tumble about in a chaotic manner while some molecules form microscopic islands of frozen order. The opposite occurs just below the freezing point. The islands of solid order become much larger and the lakes of chaotic fluid become smaller: “But right at the transition, the balance is perfect: the ordered structures fill a volume precisely equal to that of the chaotic fluid. Order and chaos intertwine in a complex, ever-changing dance of submicroscopic arms and fractal filaments” (Langton, cited in Waldrop 1992, pp. 229–230).

Langton’s description is consistent with the behaviour of other physical systems and with computer simulations carried out by scientists who study the nature of complex adaptive systems. Such systems are characterised by surprisingly dynamic behaviour and by structures that grow, split, and recombine with astonishing complexity. It is at this phase transition, at the edge of chaos, where the components of the system never quite lock into stasis, nor do they dissolve into turbulence. At the edge of chaos, the rich, complex interactions among the system’s elements make the entire system evolve to higher levels of organisational complexity. At these levels the elements of the system are more adaptive, more spontaneous, more alive. They can self-regulate while generating elaborate and novel behaviours, functions, or characteristics. In short, complex adaptive systems tend to bootstrap themselves upward to higher levels of complexity when they find the edge of chaos.

THE CHAOS-ORDER CONTINUUM

The continuum is described in chapter five of this book so only a brief overview is provided here. Consider a continuum of individual and group behaviour ranging from chaotic disorder and confusion at one extreme to perfectly logical and comprehensible order at the other. A complex adaptive system seems to evolve over time, sometimes settling into states of orderly stability, and at other times fluctuating in states of chaotic disequilibrium (Kauffman 1995; Langton 1989). At some point in the region between chaos and order the system can enter a *phase transition* in which it develops complex adaptive or evolutionary behaviour. Computer scientists Chris Langton and Norman Packard called this point the *edge of chaos* (see Kauffman 1995; Packard, 1988; Waldrop 1992). It is along this edge that the system can develop to higher levels of organisation.

In Figure 1 in chapter five of this book, the edge of chaos is portrayed as a vertical arrow along which complex behaviour in a system tends to occur. The zone of complexity represents the tendency for complex behaviour and development to occur when a system is near the edge of chaos, and to diminish when the system moves toward either extreme of the continuum. In keeping with the unpredictable nature of complex systems, the edge of chaos is not firmly fixed in the middle of the continuum. Instead, it is elusive and transitory, shifting position somewhat toward either order or chaos according to changing conditions in the context in which the system is embedded.

Table 1, which is adapted from the figure in chapter five in this book shows a collection of educational phenomena mapped onto the continuum. The table illustrates how excessive order, excessive chaos, and the exquisite balance between chaos and order can occur in the various dimensions of the educational experience. This mapping foreshadows the analyses to come later in this chapter.

Table 1. Educational phenomena mapped onto the chaos-order continuum.

EDUCATIONAL PHENOMENA	*EXCESSIVE CHAOS*	*EXQUISITE BALANCE*	*EXCESSIVE ORDER*
Educational Philosophy	Student-centred scattershot	Student-centred constructivism	Rigid, teacher-centred essentialism
The Science and Art of Teaching	Art of teaching	Blending science and art	Science of teaching
Classroom Management	Laissez-faire (jellyfish)	Student-centred democratic (backbone)	Authoritarian (brick wall)
Long-Term Career Development of Teachers	Disorganised wandering	Purposeful, long-term, creative professional development	Desperately holding to what works

(Continued)

Table 1. Continued

EDUCATIONAL PHENOMENA	*EXCESSIVE CHAOS*	*EXQUISITE BALANCE*	*EXCESSIVE ORDER*
School Reform	Inconsistent, incremental change based on chasing fads	Thoughtful long-term improvement based on creative experimentation	Hyper-mechanistic accountability mania
Domain Specificity and Curriculum Integration	Curricular disorganisation	Intricate, interdisciplinary curriculum integration	Rigid, domain specific silos
Assessment	Impulsive (shaking out a grade)	Authentic	Superficial, obsessive quantification
Instructional Models and Strategies			
Content organisation	Disorganised note taking	Mind mapping	Linear outlines
Concept learning	Random coverage of decontextualised concepts	Concept attainment and formation models	Rote, decontextualised memorisation
Inquiry learning	Directionless: students told to explore but lack sufficient guidance	Discrepant event generates keen interest, hypothesising, and hypothesis testing	Didactic: teacher demonstrates and then gives the answers
Cooperative learning	Directionless: students told to collaborate but don't know why or how	Student collaboration coheres around exploration of interesting content and processes	Rigid structure makes collaboration superficial or meaningless
Dealing with controversial issues	Relativism	Jurisprudential model	Dogmatism

FINDING THE ZONE OF COMPLEXITY IN THE CLASSROOM

Most teachers would not take seriously a suggestion that promoting chaos in their classrooms might be beneficial. But it could be that good teachers are particularly adept at finding the edge of chaos, thereby helping their students discover the zone of complexity. Using the growing knowledge of complex adaptive systems as an interpretive lens we can begin to analyse teaching innovations, models, strategies, practices, and dispositions for their promise as complexity generators. We can place them at approximate locations on the chaos-order continuum and determine their potential for enabling students to grow in dynamic, creative ways along the edge of chaos. Competing educational philosophies show up on opposite ends of the continuum. Also, any good veteran teacher knows that teaching is a blend of science and art. “Scientific” decisions fit in one sector of the continuum while “artistic” decisions fit in another. The dynamics of classroom management certainly can be mapped onto the model. A teacher’s career can show interesting shifts back and forth along the continuum. The continuum also has implications for school reform. Dynamic tensions and promising combinations of domain specificity and interdisciplinary learning can move along the dimensions of the model. So can various forms of assessment. Finally we can analyse the ways in which the employment of various instructional models and strategies can move the students’ minds from the counterproductive extremes at either end of the continuum into productive, complexity generating space in the middle. The overviews in the subsections to come follow the pattern established earlier in table 1.

Educational Philosophy

If there are to be dogmatic arguments in a profession they usually emanate from implicit philosophical influences that create opposing, often vigorously warring camps (see Ambrose & Sternberg, 2012; Ambrose, Sternberg & Sriraman, 2012). This certainly is the case in education (see Canestrari & Marlowe, 2010). Philosophical pendulum swinging has occurred frequently and the direction of the pendulum usually depends on which shortsighted policymakers are in control of a nation’s political system at a particular time. The analysis here is based largely on the American experience because American education is particularly prone to philosophical shifts based on ideological conflict.

The philosophy of essentialism often holds sway in American education. Essentialists believe in the importance of academic content learning, usually defined in domain-specific ways. They also emphasise clarity, precision, and quantitative measurement so the curriculum often is very clearly defined. When taken too far, essentialism becomes rigid and the curricular precision becomes carved in stone; consequently, teaching and learning become excessively mechanistic and drained of creative, purposeful exploration.

At the other extreme, policymakers and educators strive to create as much freedom for the student as possible. Pursuit of interests and passions are encouraged. When mismanaged or taken too far, this approach to student-centred learning lacks coherence and students end up drifting through a fragmented, ill-defined, ephemeral curriculum.

As we’ve seen, it is difficult for complex adaptive systems to find and preserve the exquisite, complexity generating balance between chaos and order at the edge of chaos. The same applies to educational philosophy. Nevertheless, some creative educators and purposeful school systems have managed to discover that complexity generating point on the continuum more often than not. Those that do make the discovery find a way to combine the need for some order with the need for significant student freedom. These needs usually are considered to be in opposition but when they can be combined the results are impressive.

For example, the Roeper School in Bloomfield Hills, Michigan has maintained a student-centred philosophy for decades (see Ambrose, Sriraman, & Cross, 2013). Students have considerable freedom to discover their own interests and pursue them, and to make significant decisions in other dimensions of their educational experience. Administrators do manage the school and teachers do teach but they deliberately exert as little control as possible over student decision making and push responsibility toward the students with frequency and determination. For example, students serve on important leadership and hiring committees normally reserved for adults in other institutions. Thinking of the school as their own institution, students tend to embrace this responsibility and rise to the occasion. Consequently, students take responsibility for mentoring younger students and ensuring that the student-centred philosophy remains vigorous. Current students, administrators, teachers, board members, and alumni are fond of telling stories about ways in which students collaboratively and spontaneously solve problems that most would think require top-down managerial intervention.

On the scale of the individual, I recall frequently visiting a second-grade classroom in a New Jersey school a few years ago. An impressive student teacher was working with a 32-year veteran mentor teacher to learn the craft. The student teacher was a career changer: a former advertising executive from New York City. She was intelligent, articulate, interpersonally adept, and highly purposeful about her transition into the teaching profession. However, she was lost during the first couple of weeks in the classroom setting. The complexity and intricacy of the curriculum and learning processes established by the mentor teacher were overwhelming. I must admit that during my visits I was lost as well. Fortunately, when the student teacher managed to make sense of the complexity, she and her mentor became a dynamic duo. The elaborate, student-centred instruction and the high-powered, intrinsic student motivation they generated were nothing short of magnificent. The student teacher managed to find patterns in the chaos of her beginner's mind, resist the temptation to find and adhere to excessively ordered processes that might ensure survival, and joined her veteran mentor in the complexity generating space at the edge of chaos.

Scientific Control and Artful Navigation

Other educational phenomena reveal tendencies for the student, the teacher, the classroom, or the school to oscillate along the chaos-order continuum. For instance, effective teaching seems to combine scientific and artistic processes (Eisner 1993; Gage 1978; Marzano, 2007). A large body of educational research provides a scientific basis for decision making in the classroom, but in spite of all the research-based guidance at our disposal there is no generally accepted pedagogical cookbook.

Many aspects of teaching must be characterised as artistic in nature because the teacher's role is too complex for strict reduction to scientific prediction and control. Teaching may never become predominantly scientific because educators must deal with the multidimensional and unpredictable properties of classroom dynamics (Doyle, 1986). These ambiguity generating properties forcefully push the classroom toward the chaotic end of the continuum and require artful, conceptual juggling from busy teachers who cannot scientifically control much of the learning process nor accurately predict more than the narrowest range of outcomes.

The science and art of teaching fit on the chaos-order continuum. Teachers who crave order obsessively stress the prediction and control offered by behavioural objectives, timetables, habitual procedures, meticulous records, and standardised test scores. Teachers who are uncomfortable with excessive order can overreact by loosely structuring the curriculum, by vacillating over procedures, and by keeping sloppy records. Those on their way to becoming master teachers are willing and able to blend the artistic and scientific aspects of teaching by carefully planning and following procedures but flexibly deviating from those plans when situations warrant. Focused but flexible curriculum planning and instructional processes enable teachers to elevate their classrooms to higher levels of complexity along the edge of chaos.

Chaos, Order, and Complexity in Classroom Management

Classroom management maps onto the continuum very well because the words chaos and order tend to permeate discussions of student behaviour. Coloroso's (2002) system of classroom management and discipline provides a particularly effective example of the chaos-order continuum. Coloroso established behaviour-management guidelines that demand general direction and shaping from the teacher while requiring responsible initiative from students. Three helpful metaphors underpin these guidelines by portraying three typical discipline styles—the brick wall, the jellyfish, and the backbone. Brick-wall teachers establish rule-bound, autocratic, coercive command. Jellyfish teachers provide insufficient structure or guidance for students because they don't establish clear expectations and they chaotically vacillate over infractions. Backbone teachers provide structure and guidance while placing responsibility for students' decisions and actions on the students themselves. According to Coloroso, the brick wall style of classroom environment stifles initiative and promotes rebellion, the jellyfish environment promotes anarchical testing of nonexistent limits, and the backbone environment encourages students to engage regularly in the complexities of creative problem solving pertaining to classroom-management issues.

Interestingly, student responses to each environment look very much like intuitive attempts to find the edge of chaos. Rebellion against the excessive order of the brick wall style may be an attempt to make the environment more chaotic, which is a movement from the extreme, right-hand end of the continuum toward the centre.

Testing nonexistent limits in a chaotic, jellyfish environment may be an attempt to provoke the teacher into imposing the missing order that normally would be provided by a caring adult. Such provocation pressures the classroom system to move from the extreme left-hand end of the continuum toward the centre. The development of creative problem solving and decision-making capabilities in the backbone classroom may result from the children bootstrapping themselves upward along the edge of chaos to higher and more complex levels of conceptual development because effective decision making is based on higher-order thinking abilities (Elder & Paul, 2012; Resnick 1987).

Aiming for Complexity in Career Development

From a long-term viewpoint, teachers' careers can be characterised as oscillations along the continuum. Most teachers go through three stages in the course of their careers: a beginning survival stage, a consolidation stage, and a mastery stage (Feiman-Nemser 1983, 2001). Beginners tend to be most concerned with their own personal survival, particularly in terms of classroom management. In the consolidation stage, teachers become more confident because their goals clarify and teaching routines are more habitual. In the mastery stage, teachers have mastered instructional strategies and classroom management. This frees them to expand their pedagogical repertoires while deepening their understanding of subject matter.

Looking at these stages from the viewpoint of the chaos-order continuum, many beginning teachers are overwhelmed by the unpredictable, complex, sometimes chaotic nature of the classroom and by the uncertain, intangible, artistic aspects of the profession. They still have their professional training wheels on so they have not yet developed automaticity--the ability to subconsciously and automatically apply pedagogical and management tools. Consequently, they yearn for order and spend their first few years pendulum swinging away from the chaos end of the continuum toward order by mastering highly prescriptive strategies. As they approach the order extreme of the continuum, they tightly embrace the pedagogical tools that derive from the research base of the profession. As more time passes, those who will become excellent veteran teachers eventually grow more flexible and position themselves near the middle of the continuum by relinquishing the excessive order of overly prescriptive practices. They retain such practices in their teaching repertoires but hold them lightly, artfully sensing when their use is appropriate.

These three general locations on the continuum may have something to do with the contradictory phenomena of teacher self-actualisation and teacher burnout. Teaching is a wonderfully enriching career for some, yet a high-stress, low-reward occupation for others. Teacher self-actualisation may emerge from discovery of the edge of chaos through integration of the scientific and artistic aspects of teaching, and the subsequent evolution of a teacher to higher levels of conceptual complexity.

Some burned-out teachers may still be locked in the survival stage because they couldn't manage to integrate pedagogical science and art and, consequently, never found the edge of chaos. They remain mired in the chaotic extreme of the continuum, perpetually wandering in the midst of chaos produced by the unpredictability and multidimensionality of the classroom.

Others may have managed the pendulum swing from chaos to order only to have been seduced by the artificial tranquility of overly scientific management and pedagogy. For teachers trapped at the order end of the continuum, burnout may come from an intuitive sense that their excessive attention to order has created an artificially sanitised classroom environment lacking in the conceptual complexity characteristic of true growth in students and teachers. It also may come from the tension produced by students who persistently attempt to force their way out of such a sterile environment in their own efforts to find the edge of chaos.

School Reform Through Excessive Order

In light of the chaos-order continuum, innovations or school-improvement initiatives should be carefully assessed for their complexity generating potential. Initiatives that force the system toward the extremes of the continuum are likely to be counterproductive, or at best ineffective over the long term.

For instance, much of what passes for school reform today may derive from ill-informed, reactionary attempts to re-establish order in the face of mounting societal chaos. A number of trends in society are generating a great deal of unpredictability in the educational system. An increasingly multicultural and ideologically diverse population exerts strong and conflicting pressures for change in our schools (Berliner & Biddle, 1995). Other societal influences on the classroom, such as drug abuse, violence, and eroding family structures, create additional confusion (Cohen, Higgins, & Ambrose, 1999). As if this isn't enough, teachers must help their students master bodies of knowledge that are rapidly evolving and exponentially growing in most fields.

As we have seen, when beginning teachers are positioned at the chaotic end of the continuum they tend to push vigorously past the edge of chaos toward the opposite extreme--toward excessive order. Our society may be behaving in a similar way in reacting to the chaos of the postmodern era by insisting that school reforms be driven by high-stakes standardised testing for accountability purposes. The quantitative scores provided by standardised tests are seductive to those who crave order because they represent the order of seemingly absolute quality standards in the midst of conflicting goals and intangible instructional outcomes. The No Child Left Behind (NCLB) legislation was an especially pernicious manifestation of societal angst over chaotic sociopolitical and educational phenomena. The same can be said for somewhat less toxic recent reform initiatives such a Race to the Top. These pressures for reform force schools to fit student learning into excessively simplistic and mechanical standardised achievement and accountability frameworks (Apple, 2007; Berliner, 2012; Kumashiro, 2012; Meier & Wood, 2004; Ravitch, 2010, 2013). But standardised tests should not be used primarily as accountability measures because they measure only limited aspects of cognition (Berliner, 2012; Eisner, 1994; Kohn, 2000; Ravitch, 2010, 2013). Teachers who are held accountable for student progress in the more measurable, superficial skills will be inclined to ignore important dimensions of students' abilities that are not measured by the tests. Unfortunately, a chaotic society that is desperately seeking order readily embraces standardised test misinterpretation for questionable purposes. Such accountability measures encourage teachers to teach to the test, thereby narrowing, fragmenting, and trivialising the curriculum (Berliner, 2012; Kohn 2000). As our school systems acquiesce to excessive demands for order from a chaotic, reactionary society, students and teachers are driven further away from the zone of complexity toward sterile, artificial, excessive order. This addresses the shortsighted, superficial dimensions of school reform.

But there is another, more pernicious, arguably psychopathic dimension of the reform movement. Powerful profiteers are using the public angst over trumped up public school "failures" as cover for their more insidious agenda. They hope that constant, long-term berating of the public school system will undermine it and cause it to crumble leaving hundreds of billions of taxpayer dollars for the taking (see Ravitch, 2013). The privatisers who want to pick through the rubble of the public system looking for profiteering opportunities will do whatever they can to dismantle regulation and provide a free-for-all environment. Some limited productive innovation could occur under these conditions but it is much more likely that privatisation will lead to near sweatshop conditions. This would represent a rapid move into the chaotic end of the chaos-order continuum because the sense of democratic purpose embedded in the public school system will be replaced by a large number of fly-by-night privatised schools with profit-seeking is the primary goal instead of the well-being of young people in their charge.

In both scenarios--the transformation of the public education system into a rigid, excessively ordered, accountability driven structure, or a chaotic, turbulent collection of deregulated, transient profit seeking organisations--American education would reside in the counterproductive extremes of the chaos-order continuum. A third scenario in which the American public awakens to the misguided and unethical dogmatism of the reformers could enable a redoubling of effort to realign the public education system with its initial goals of enhancing the life chances of young people while strengthening the democratic fiber of the nation. It also could capitalise on recent trends toward bottom-up teacher leadership. In recognition that the teaching workforce includes impressive, purposeful, and knowledgeable potential leaders, the teacher-leadership trend is bringing the most impressive teachers together to jumpstart school improvement initiatives (Danielson, 2006; Fisher, Frey & Pumpian, 2012). Reinvigorating the public system through initiatives like teacher leadership looks very much like excursions through the complexity generating space in the middle of the chaos-order continuum.

Domain Specificity Versus Curriculum Integration

The notion of domain-specific expertise garners much attention in the fields of creative studies and gifted education today (see Baer, 2012, 2013; Kaufman & Baer, 2005; Subotnik, Olszewski-Kubilius, & Worrell, 2011). The talent development or creativity of a high-potential student can be conceived of as domain general, domain specific, or a blend of the two. The term domain general implies that abilities transfer across the borders of professional fields, academic disciplines, and other domains of human activity. For example, a prolific idea generator could have the potential to be prolific in the biological sciences or in mathematics. In contrast, the term domain specific implies that an individual with impressive abilities in mathematics may not have the capacity to be nearly as able in the biological sciences, or in other fields.

The idea of domain specificity certainly is helpful and relevant in today's complex environment in which knowledge grows rapidly. It would be difficult to master the knowledge in one discipline let alone in multiple disciplines and it is likely that different domains require different blends of skills and knowledge. But if we push the construct too far it might lead to a form of dogmatic rigidity at the extreme order end of the chaos-order continuum.

For example, professionals might be locked too firmly within their discipline-specific silos to appreciate ways in which knowledge connects across disciplines. I saw this occur in meetings of leading theorists and researchers who were trying to integrate diverse theories across disciplinary borders. In two weeklong conferences involving prominent scholars from psychology, philosophy, gifted education, creative studies, economics, and theoretical physics, planners attempted to initiate interdisciplinary dialogue through a number of different processes (see Ambrose, 1992, 2009). Most of these processes failed because the domain-specific inclinations of the participants prevented them from engaging in productive dialogue with one another. Whenever they attempted to find common ground they talked past one another because they couldn't understand and appreciate the theoretical frameworks and dialogic predispositions of foreign disciplines. Or, they began to engage in conflict because they misunderstood one another. Interpersonal friction per se was not the problem because all of the participants were highly intelligent, professional, and interpersonally adept. The primary problem was the inability of virtually everyone at these conferences to cross the yawning chasms between different disciplines. Consequently, the attempt to integrate theories largely failed because participants retreated into their own epistemological frameworks. This retreat can be construed as a form of dogmatism. We shouldn't disparage the highly intelligent participants for this failure because even the gifted and creative are not immune to dogmatism (Elder & Paul, 2012). Nevertheless, dogmatic insularity sabotaged the interdisciplinary proceedings of both conferences.

It is appropriate and important to emphasise domain-specific learning but that should not preclude attempts to teach interdisciplinary skills and dispositions. Students should learn to value the processes of cross-disciplinary knowledge integration and pattern finding. This is important for a number of reasons, not the least of which is the need for today's citizens to understand the enormous issues of the 21st-century globalised context. In a democracy, the citizenry must be knowledgeable about the issues that impact their nation and region (see Ambrose, 2005; Hacker & Pierson, 2010; Litke, 1997; Wolin, 2008). Without such awareness democracy erodes and unscrupulous elites can take excessive control of the socioeconomic and political apparatus. This tends to benefit them in the short term while costing the vast majority and society as a whole an enormous amount over the long term.

Students require extra help to understand 21st-century issues because those issues take the form of macroproblems and macro-opportunities (see Ambrose, 2009; Ambrose & Sternberg, 2012). Macroproblems are interdisciplinary because they cannot be solved from within the borders of a single discipline. They are international because they cannot be solved from within the borders of a single nation, no matter how powerful. They are long term because they took decades or even centuries to create and will take long periods of time to solve. Examples of macroproblems are climate change, increasingly extreme socioeconomic inequality within and between nations, and looming shortages of important natural resources. Macro-opportunities are unprecedented possibilities for enormous, widespread improvements in societies. An example is the emerging, global electronic networking of diverse minds for the solution of macroproblems.

Even if we justify interdisciplinary approaches to teaching only by invoking the importance of knowledgeable citizenship in view of 21st-century macroproblems and macro-opportunities, these approaches are worth pursuing. But the development of transdisciplinary Renaissance thinking can benefit individuals as well. Creative ideas for work or personal enrichment can emerge from the unexpected combination of ideas across disciplinary borders (see Ambrose, 2009).

Fortunately, there are some very helpful models for interdisciplinary learning. Educational theorists and researchers use the term curriculum integration for this kind of work (Jacobs, 1989; VanTassel-Baska , 1994; VanTassel-Baska & Stambaugh, 2006). Educators implementing an integrated-curriculum approach tend to use interesting themes as focal points for study throughout different subject areas. For example, students can use the theme of conflict to study various wars in social studies, battles over paradigms in the sciences, difficulties between characters in English literature novels, the workings of the immune system in biology, the dynamic tensions between genres in the arts, and more.

While silo entrapment represents a form of dogmatic insularity at the excessive order end of the chaos-order continuum, a jumbled, grab-bag approach to the curriculum established by a disorganised teacher would represent entrapment at the excessive chaos end. Curriculum integration has the advantage of establishing a blend between domain-specific learning and interdisciplinary connection making. Students still have to learn the knowledge, skills, and dispositions of the discipline while studying science, mathematics, literature, social studies, and the arts through the lens of the conflict theme but they also have opportunities to make creative, cross-disciplinary connections by using that theme for interdisciplinary bridge building. Once again, we see how teaching and learning can find the optimal, complexity generating space at the edge of chaos near the middle of the chaos-order continuum.

Authentic Assessment Versus Superficial, Obsessive Quantification and Impulsivity

In today's climate of frenzied, opportunistic, shortsighted school reform, teachers and students spend far too much of their time in testing situations, making their way through tedious, superficial standardised tests (see. Berliner, 2012; Kumashiro, 2012; Ravitch, 2010, 2013). The superficial qualification imposed by this testing pushes the students toward the excessive order end of the continuum.

Some teachers still can be found at the chaos end of the continuum because they are inclined to shake out grades through the use of impulsive assessment. They know the administration requires assessment but they either lack the expertise to proceed with effective assessment or they simply are not inclined to do this important work.

Contrasting with both of these ineffective and harmful approaches to assessment, the more creative, purposeful, courageous teachers do what they can, to the extent possible, to shrug off the superficial reformers, and employ authentic assessment to determine the extent to which students are learning important knowledge, skills, and dispositions. Authentic assessment entails the use of more complex, nuanced measurements. For example, elaborate portfolios and case studies of student work provide rich data and insights that are inaccessible to standardised measures, no matter how clever the test makers may be (see Darling-Hammond, Ancess, & Falk, 1995). The diligent, purposeful, highly creative work of those who implement effective authentic assessment takes place at the edge of chaos in the middle of the continuum.

Complexity Generating Instructional Models and Strategies

Fortunately, some other pedagogical practices are ideally suited to finding the edge of chaos. Educators who nurture these practices can help counter the measurement mania that is sweeping the nation. Many forward-looking school leaders and teachers embrace the use of student-centred instructional models and strategies. These approaches can generate productive complexity because they are based on students' interests, loosely defined yet purposeful guidance from the teacher, and multiple options for research and learning. Here, I provide brief overviews of some examples of instructional models and strategies that can be used to help students avoid excessive order or excessive chaos so they can discover the highly motivating, complexity generating space in the middle of the continuum near the edge of chaos.

Mind mapping versus linear outlines or disorganised note taking. Consider some ways in which students can organise their learning and establish frameworks for organising learned concepts. One common way to do this is to use linear, bulletpoint outlines. These certainly are helpful and provide a sense of logical coherence to the organisation of large amounts of information; however, they lack some creative generative power. Once you create a linear outline it can seem somewhat cast in stone and resistant to revision. This resistance can place it near the excessive order end of the chaos-order continuum.

In contrast, students who have not been taught very well how to organise information might end up with scattershot collections of concepts distributed throughout computer files or multiple binders. The collections lack logical or integrative coherence. These students will be somewhat lost and purposeless because they are drifting around in the excessive chaos end of the continuum.

But a teacher can provide the best of both worlds (logical coherence and creative idea generation) by teaching students to use concept organisers such as mind maps. A mind map is a nonlinear idea generator and concept organiser that begins with a concept in the middle of a page or computer screen and then branches out into subcategories (Buzan, 2012). These subcategories then sprout their own branches, which in turn sprout even more branches of their own. The growth of a mind map looks like the growth of an organic, plant-like system. Figure 2 shows an example of a mind map that was designed to illustrate the potential of graphic organisers or *nonlinguistic representations* (see Marzano, Pickering, & Pollock, 2005). Nonlinguistic representations are visual thinking strategies for organising and mastering content. A mind map is a particularly powerful form of nonlinguistic representation.

Mind maps can be hand drawn, as in the example in Figure 1, or they can be generated through the use of computer programs. Many such programs exist in the form of freeware or commercial software. A particularly interesting attribute of the mind mapping process is the way in which generative creativity tends to accelerate as the map grows. In contrast with creative brainstorming, which tends to slow down as we "use up" our store of ideas about a topic, the mind map produces more and more branches as it develops. Consequently, as time moves forward there are far more branches inviting additional connective ideas than there were in the early stages of the map's development.

Students can generate their own maps alone or in collaboration with others to capture what they know about a topic and to guide their thinking about investigating the topic further. Or, a teacher might initiate an integrated curriculum unit of the sort mentioned in the previous subsection by asking students to develop a mind map outlining their prior knowledge of, and most pressing questions about, a theme such as exploration. The theme becomes the focus for active investigation that integrates several subject areas. Story writing, spelling discoveries, mathematics questions, artistic works, and scientific research projects all emerge from the web. These processes combine to produce a highly complex, interactive network of dynamically evolving knowledge (Jacobs 1989).

From the viewpoint of the chaos-order continuum, this approach to learning nudges the classroom inward from the extremes of chaos and order toward the zone

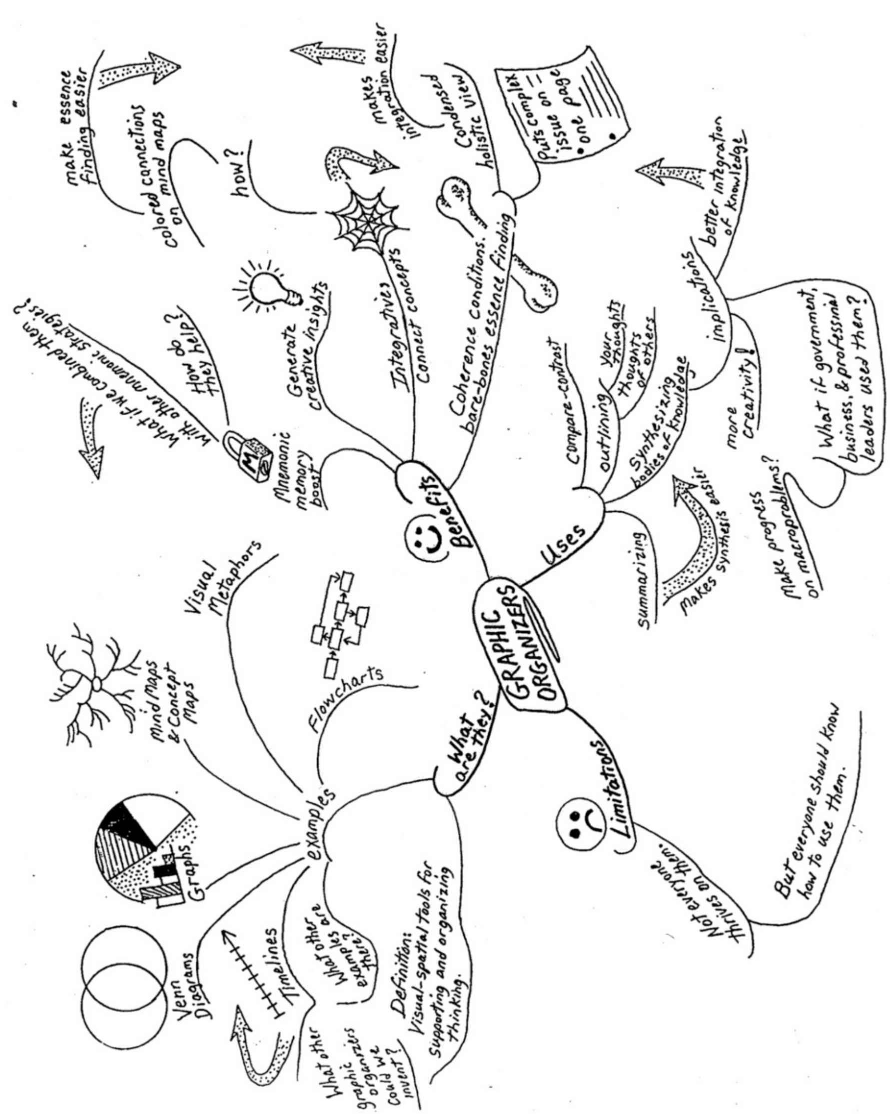

Figure 2. Example of a hand-drawn mind map.

of complexity. The student-generated web and facilitative guidance from the teacher provide a loosely ordered yet coherent and highly motivating structure for learning. The structure provides order, but not extreme order. Within the structure there is much latitude for open-ended exploration of individual interests. This latitude generates some chaotic unpredictability because not all students are doing the same thing at the same time as in a traditional classroom. The chaos, however, is mitigated by the guidance of the exploratory theme, and by the facilitative leadership of the teacher.

Concept attainment and concept formation. Two other teaching models also engage students in building their own knowledge of concepts while experiencing complex adaptive behaviour in the classroom. A teacher using the concept attainment variation of the concept learning model engages students in inductive reasoning by presenting them with examples and nonexamples of a concept (Bruner, Goodnow, & Austin 1956; Joyce & Weil 2000; Rettig & Canady, 2013). Students look for common attributes among the examples, and for ways in which the nonexamples differ from the examples. The goal of discovering and defining the intriguing mystery concept focuses students' minds and provides order in this teaching model, yet this order is not overly restrictive. Students have the freedom to explore the ambiguous space of multiple possibilities before zeroing in on a precise concept definition. In contrast, a teacher who defines the concept for the students at the beginning of the lesson and then proceeds to provide examples that refine the definition may be establishing excessive order at the expense of the initially interesting chaotic ambiguity. This excessive order becomes especially burdensome when the teacher expects students to rote memorise the received concepts and definitions and then spit them back in superficial testing situations.

The concept formation model is a powerful cousin of concept attainment. It also is student centred but it's operation looks very different. Instead of a teacher presenting students with paired examples and non-examples, as in concept attainment, she or he introduces students to a complex, intriguing topic and asks them to do some preliminary research. Once the students have some familiarity with the topic they generate a brainstormed list of impressions, facts, and questions they pick up through this initial exposure. After that, the teacher asks them to categorise the elements of this list and label each of the categories. Students can revise their categories at any point. For example, they might eliminate one category and move its elements under one or more other categories. Or, they might combine two categories into one, or split one category into several new categories.

The process can be very dynamic and students make all of the decisions. After creating and naming the categories, they use this work to develop generalisations about the topic. For example, students exposed to readings and Internet searches about the Roman Empire might come up with a large number of impressions and facts such as the following: they had very well organised armies; some of their entertainment was brutal involving gladiatorial combat; they created impressive aqueducts to bring water into the cities; they pacified conquered peoples in the empire by making them citizens, and so on. After creating an extensive list of impressions and facts the students might create categories such as *organised practicality*, *hierarchical dominance*, and so on. After modifying their categories they write a paragraph or two summarising what they've learned about the Roman Empire. The process burns the topic into their long-term memories because they created the knowledge themselves instead of passively receiving facts from a teacher or a textbook. The complex, intrinsically motivated nature of the concept formation process places it in the middle of the chaos-order continuum where complex learning takes place.

Inquiry learning. The problem-based, inquiry learning model also draws students into the zone of complexity. A teacher using this model presents students with a puzzling situation or discrepant event (Arends & Kilcher, 2010; Krajcik, Blumenfeld, Marx, & Soloway 1994). Students are encouraged to question, hypothesise, explore, and experiment in order to discover underlying causes or principles that can explain the situation or event. It is the mystery of the discovery process that provides this teaching model with its complexity generating properties. The need to discover generates interest, which naturally structures the learning process. Students are purposefully engaged in research, probing through multiple possibilities for explanation of the mystery. The situation or event is ambiguous enough to avoid excessive order, yet it provides enough subtle clues to keep students from aimlessly wandering through conceptual chaos; consequently, it pushes students into the productive, complexity generating space in the middle of the continuum.

Cooperative learning. The cooperative learning model also can generate complex thought and behaviour. The several variations of the model each engage students in collaborative, small-group studies or investigations. Individuals carry responsibility for the success of the group and vice versa (Arends & Kilcher, 2010; D. Johnson & F. Johnson 1994; Killen, 2006; Sharan 1990; Slavin 1995). On the surface, most cooperative learning is highly ordered because objectives are clear and students are assigned specific tasks with distinct procedures for completion. But the teacher cannot with certainty predict or control a cooperative learning lesson. Students have varied backgrounds, knowledge bases, and interests that create unique perspectives on common problems. Small-group interactions bring these varied perspectives into contact, and this generates some ambiguity and tension in the learning process. Moreover, the teacher cannot completely control the process because she or he cannot be sitting with each of the groups in the classroom at all times. When with one group, another group might spin off in an unexpected direction. These unpredictable aspects of the process may be productive or unproductive but they inject some chaos into the classroom. If the teacher ensures that cooperative learning group processes are focused and purposeful, to the extent possible, the dynamic tension between procedural order and unpredictable, chaotic student interaction can draw a classroom into the middle of the chaos-order continuum.

The jurisprudential model. In spite of the best efforts of some school reformers to sanitise the curriculum of anything debatable so they can impose a dogmatic ideological slant, some opportunities for grappling with controversial issues remain. Dealing with controversy is an opportunity for generating higher-order thinking because such thought enables individuals or groups to navigate through shades of gray instead of falling for black and white, polarised conceptions (Resnick, 1987; Elder & Paul, 2012).

Fortunately, the jurisprudential instructional model provides an effective way for students to address controversial issues (see Arends & Kilcher, 2010; Joyce & Weil, 1992). When using the model the teacher introduces students to the controversy through any of a number of processes (e.g., a brief reading, an Internet search, a guest presentation or debate). After the introduction, students are asked to carry out research to gain a deeper understanding of the issue. They are encouraged to withhold judgment to the extent possible so they can capture as many dimensions of the issue as possible. After that, the class convenes to create a three-column jurisprudential table. They identify two opposing positions on the issue. Position A goes at the top of the first column of the table. Position B goes at the top of the third column of the table. Students carry out in-depth discussions to determine the arguments and supporting evidence for each position. The arguments and evidence supporting position A go in the first column. The arguments and evidence supporting position B go in the third column.

For example, the teacher exposes students to arguments over the nature of capitalism in the 21st century. After exploring various sources on 21st-century capitalism in as much depth and detail as possible students decide that position A should be labeled as follows: “capitalism is a highly beneficial economic system.” They decide that position B should be labeled as follows: “capitalism is damaging and unethical.” After that, they build the table by loading in supporting arguments and evidence for both sides. Examples of supporting arguments and evidence for position A include the following: “before capitalism, humanity suffered from the injustice of feudalism”; “capitalism is making Third World countries richer”; and so on. Examples of supporting arguments and evidence for position B include the following: “capitalism is generating severe inequality within and between nations”; “runaway capitalism produced the 2008 economic collapse”; and so on.

After completing these two columns, students determine a middle-ground compromise position that will fill in the blank middle column of the table. The guiding rule during this phase is that the compromise position can lean somewhat toward either position A or position B but it cannot grossly violate either one. This prevents students from falling back into one of the polarised positions. After much deliberation, students determine that the compromise position will be labeled “nuanced capitalism.” Now they are nearing completion of the process. The final phase is to load in arguments and supporting evidence for their compromise position. Some of the points they include in the middle column are as follows: “Adam Smith, generally recognised as the father of capitalism, was enthusiastic about it but recommended prudent regulation instead of laissez-faire processes”; “Examples of capitalism that benefit the poor exist. For example, the system of microcredit created by Mohammed Younis, Bangladeshi banker to the poor, has lifted millions of poor people, mostly women, out of poverty in the Third World"; and so on.

Students who never think about difficult, controversial issues may find their minds wandering at the chaotic end of the chaos-order continuum when confronted with the cognitive complexity and emotional fervor controversies typically entail. Other students who do think about controversial issues but think about them only superficially usually find themselves trapped within the rigid dogmatism of a particular belief system, such as an influential ideology. This represents entrapment at the excessive order end of the continuum. Students who are fortunate enough to experience the jurisprudential model can engage in nuanced, higher-order thinking by building the compromise position. In so doing they discover the complexity generating edge of chaos in the middle of the continuum.

These models are only a few of many intriguing constructivist approaches to teaching and learning. They are presented here as illustrative examples of promising methods that may prompt educators to look for the complexity finding potential in all of their classroom processes. In short, strategies, models, and curriculum-development approaches that promote the growth of conceptual complexity in the classroom share important characteristics. They capitalise on the dynamic tension generated between general, but imprecise, order-producing frameworks for organisation, and ambiguity generating processes that capture students' interest. It is this tension that enables skillful teachers to navigate their classrooms artfully between excessive order and excessive chaos.

CONCLUSION

Public schools are under attack by critics and influential media pundits who are somewhat ill-informed at best, or disingenuous, manipulative, and ruthlessly exploitative at worst (Berliner, 2006, 2012; Berliner & Biddle 1995; Cohen, Higgins, & Ambrose 1999; Kumashiro, 2012; Nichols & Berliner, 2007; Ravitch, 2010, 2013). If a school or school system is to survive and purposefully improve in substantive ways, its educators must learn to recognise and deal with the superficial banalities of externally imposed high-stakes, test-driven reform agendas. In the last few decades, American society has been in a state of chaotic socioeconomic and cultural flux that is generating great pressure for simplistic, reactionary school reform. Creative educators who perceive patterns of opportunity in turbulent school and societal conditions can see through the temptations of reforms that are based on the intellectually barren predictability of excessive order. They can cut through the chaos of conflicting public demands and shape school improvement at the grass-roots level, thereby promoting the complex conceptual development that will enable students to cope with the demands of an ever-changing world.

The chaos-order continuum is a simple conceptual tool that can resonate viscerally with the day-to-day experiences of taxpayers and policy makers. As such, educational leaders can use it to combat the misguided critics by educating their constituencies about the dangers of simplistic reforms, and the high potential of artful, professionally driven instructional improvements.

Aside from school-reform struggles, creative teachers can look for opportunities to discover the zone of complexity in their own classrooms. Like the ancient Greek navigators, they can perceive patterns of opportunity in rapidly unfolding events. They can use student-centred teaching strategies and models to steer their classrooms artfully between the rock of excessive stasis and the turbulent waters of excessive chaos. Those who successfully learn to navigate this channel will not perceive our rapidly changing world as a threat. They will embrace the ambiguity of our times and take advantage of the opportunities it presents for complex development and creative, productive school improvement.

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BRYANT GRIFFITH & KIM SKINNER

EXPANSIVE NOTIONS OF COHERENCE AND COMPLEXITY IN EDUCATION

What kind of coherence can be constructed in schools if our world is fragmented, decentred, and located in an epistemological gap between modernism and postmodernism? This chapter focuses on cultural narration and attends to discontinuities and disjunctions while considering complexity and coherence. It presents expansive notions of the nature of cultural narrative and its "space" in education. Despite much emphasis in research on the predictable, observable, and verifiable, education represents the interconnectedness of human beings and their diverse forms of expression. It is a site of multifaceted diversity, with each practice reflecting unique combinations of ideology, culture, and language, played out in numerous forms and permutations of multi-textual discourses. The influence of each contextual space is only limited by the ability to understand its complexity and to acknowledge it.

Education is a dance of complexity and struggle, characterised not only by unpredictability but also by the search for coherence. Despite much emphasis in research on the predictable, observable, and verifiable, education represents the interconnectedness of human beings and their diverse forms of expression. It is a site of multifaceted diversity, with each practice reflecting unique combinations of ideology, culture, and language, played out in numerous forms and permutations of multi-textual discourses. The influence of each contextual space is only limited by the ability to understand its complexity and to acknowledge it. This chapter focuses on cultural narration and attends to discontinuities and disjunctions while considering complexity and coherence. It presents expansive notions of the nature of cultural narrative and its "space" in education.

Locating culture, in particular our educational culture, as a border "in the moment of transit where space and time cross to produce complex figures of difference and identity, past and present, inside and outside, inclusion and exclusion" (Bhabha, 1990, p. 304). This complexity can and does produce uncertainty. In the past, the move from a collection of individual narratives that can define a culture and a nation to the one grand narrative of a collective group has often been missed. This is where the search for coherence becomes an explicitly dynamic concept. This may have worked in the last two hundred years, but as we slip away from the presuppositions of modernism it becomes more and more problematic. Even so, we don't give up on the search and we continue to try to stitch it together. On one level, at least, this is the role of discourse in education. As educators, our role includes not only

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 185–197.

redrawing and redefining the borders, but making them permeable. This calls for an epistemological leap, in which the history of ideas isn't a road map but a constantly changing landscape to be negotiated, step-by-step, by what Collingwood (1946) has called historical re-enactment, the tracing of historical presuppositions.

Coherence, then, like cultural narration, is fluid. It is relative, but not simply to individual discourses. Instead, coherence can be described as a reflection of what our cultural narrations hold to be the case. Our role is to frame this is such a way as to provide the tools needed to make this discussion personally meaningful and worthwhile. This border is both an epistemological and metaphysical concept and as such it is in a constant state of fluidity. Boundaries blur as our discourse is more open to different interpretations, so, as teachers and learners, we migrate between coherence and complexity often without realising or recognising it.

CULTURAL NARRATIONS

Cultural narratives are the cautionary stories of our lives within our discourse communities. As teachers and learners, we write, speak, and display them, sometimes explicitly and sometimes implicitly. In teaching and learning, one of our roles is to take these narratives and forge a shared discourse community where our thoughts can be acknowledged, discussed, and critiqued. Narratology is one way to open up the possibilities of our diverse classroom discourses (cf. Griffith, 2008).

These discourses won't be of just one type, as our world is not one voice, but we can permit ourselves to decode these discourses through the content areas in which we teach and learn. For example, we might explore with our students what a historian or biologist does, as well as what they produce. We could ask: Who wrote our history books? Whose story was told and by whom? We could also consider the academic discourse of an historian or a biologist and how it connects to the discourse of the street. As we describe and illustrate these formal discourses for our students, we also invite them to share their discourses with us. It is in the in-between spaces, these metaphorical and epistemological gaps, that learning is constructed. Ours is a fragmented world of possibility, bound and framed by cultural discourse, so we, as well as our studies, must be fluid. All of this is an on-going process of intersecting concepts that fuse and deconstruct and then reconstruct through the explicit action of our discourses. Our narratives are not situated in the past, present, or future. Instead, they cross into numerous multimodalities, becoming more like Tolkien tales in their fluidity.

The point here is that narratology permits us to create new possibilities. This isn't easy, as real change is marked by challenge and defiance. Our curriculum has the possibility to be a series of cautionary tales that point the way to the creation of new narratives. Teaching and learning in this way allows both teachers and learners to decode their narratives and provides the opportunity for a shared construction of meaning.

In the nineteenth century, Wordsworth (1850) wrote that some of his thoughts were conscious and others were hidden from words, what he called "breathings." These breathings weren't explicit but seem to have been Wordsworth's way of describing gaps or spaces. These are our narrative gaps and also our crossings, when we slide from explicit to implicit, back and forth; and they are examples of the creative power of the mind that we often miss in the formal practice of teaching and learning. Sleeping, dreaming, memory, forgetfulness, compassion, indifference, thought, and emotion cloud the border between the here and now and it is these breathings or gaps we need to uncover and discuss.

Knoespel (1991) asserted that all discourse takes the shape of story, as our personal narratives graft onto the narratives of others: "For theoreticians, the examination of such narrative networks offers a means for detecting how individuals and disciplines account for themselves" (p. 101). As teachers learn to commit themselves to the gaps revealed by the narratives of their students, classrooms become discourse communities and contact zones, co-constructing contextual discourses, which acknowledge ritual and gesture manifested in various forms of text.

The multiplicity of ways in which our students voice their cultural narrations and the various forms of their discourse needs to be understood in a shared process of decoding. We know that formal writing, like responses to the novels studied in class, and informal writing, like texting, blogging, and contributing to social networks, are common ways for students to become engaged in text. However, we must also acknowledge gestures and body decorations, such as piercing and tattoos, as these are integral to the decoding process.

The text of the street is a combination of gesture, speech, and other markers. For example, gang members often use tattoos as road maps to be read and understood within their particular discourse community. In this case, the marks that are etched in the skin of a person are considered representative of the individual's identity and affiliations. If they aren't, the bearer must answer for them. Tattoos are symbolic and contain a discourse that can be decoded and understood. Tattoos can also be regarded as a poetic history of certain aspects of one's life. While this symbolism is a mystery to some, and it is often intended to be, it is explicit to others. In schools, as teachers and learners we need to decode texts and express our cautionary tales, and tattoos, piercings, gestures, and clothing are a part of that.

Unfortunately, formal education is often based on a more narrow view of what constitutes a text. What happens then if we don't acknowledge these other forms of discourse? What we do is exclude these forms of discourse from our cultural narration. We declare them of no significance or meaning. Excluding them from our classrooms only serves to drive them underground and to make these discourses implicit and secretive. When discourse is made explicit through strategic storytelling, teaching and learning become transparent. In this way, both teachers and students are acknowledging others' voices, and that meaning is regarded, on at least one level, as socially constructed and negotiable. When the rules of the road can be read, even in a chaotic manner, opportunities arise. We can obey them, twist them, interpret them, or ignore them. In all cases, those decisions are made by individuals. This is not a matter of writing a dictionary because this, like life itself, is ongoing.

COHERENCE

If we think of our cultural narratives as as-if conditional statements about our world, they become cautionary statements that position us in a world of multiple possibilities. Our individual discourses are then multi-textual, multi-pedagogical tales about the variety of ways the world, in our case the world of teaching and learning, might be viewed. So let's not make hasty judgments about who our students are, what they expect, and how to help them learn. We'll find all that out and more if we listen to their stories and consider them as positioning tales in an uncertain world.

What kind of coherence can be constructed if our world is fragmented, decentred, and located in an epistemological gap between modernism and postmodernism? The answer is that as we migrate from one Kuhnian style paradigm to another, in a not so seamless fashion, it becomes possible to think about stepping outside the discursive borders that have been constructed to keep us in and the other out. As stated earlier, the search for coherence is not linear. The move from one set of presuppositions to another is a tenuous construction of attempts to make the previous theory work until it is clear that another set of ideas better fits the acknowledged facts. An example of this would be the various attempted fixes to Ptolemy's theory until Newtonian physics displaced it on the grounds of being simpler. One of the roles of an educator is to help learners view the world in ways that make sense. We are privileged to be able to make this view permeable and this calls for an epistemological leap in which the history of ideas that we reenact over and over again is fluid and on-going.

Bakhtin (1981) asked how communication takes place in discourse communities that divide and separate people. He used the concept of *ideological becoming* to describe how teaching and learning occur. Bakhtin also helped illuminate how learning takes place in the context of struggle: "The importance of struggling with another's discourse, its influence in the history of an individual's coming to ideological consciousness, is enormous" (p. 348). We can work through many of our current problems in education by attending to some very influential thinkers who are normally considered to be outside the field of teaching and learning, thinkers like Bhabha, Bakhtin, and Foucault. The reason for attempting to deconstruct epistemological borders is that at this particular moment teaching and learning are important concepts and forces in the construction of a new paradigm and the weaving of ideas in a different sort of coherency. This is a paradigm that is not modern, post-structural, or postmodern. It is also not colonial or postcolonial. However, these discourses have informed us that discourse is not owned by a particular culture, language, gender, and so on.

Our discourses, like our lives, are always in a state of play. They fall in and out of the weaving of our cultural narratives. This process can coalesce into a national language and define our culture, giving it coherence; yet fragmented discourses struggle to be recognised. This, too, is an historical process At times when a paradigm is said to be working, a national language can play such a role, but in time of great flux such as ours we are driven back to think about the value and role of individual cautionary tales. There is a problematical dialectic at work here. We have come to realise over the last several decades that we do not live apart from the rest of the world. It is an impossible task to turn our students into one form of "being American." If we are to change our perspective, it will be the combined cultural forces of our country that rewrite the grand narrative, but for here and now our task is a different one. It is to allow our students the freedom of choice to make wise and informed decisions.

In schooling, our conception of boundaries and borders must not be drawn without some thought given to the process. Difference should not be regarded as a set of intellectual presuppositions. Boundaries are as much metaphysical as they are epistemological. They are drawn from the inside out for a myriad of reasons. Some of these are historical; for example, the role of the learner as someone in deference to a teacher. Some are cultural, for example, that students of a particular race, gender, or socioeconomic background may not be as good of students as others. This equation is complex, as we all realise. How and what we acknowledge in our classrooms works both ways. Tradition may define the expected role that teachers play and their ability to define and enforce the role of students, but tradition itself doesn't act as the sufficient condition.

We have become aware that language informs discourse, that concepts such as ideology can have such different meanings from culture to culture. We know that the discourses of the postcolonial world are not just academic posturing. They are real and they exist, as our students continue to arrive with diverse backgrounds from the global classroom. Teachers can play a key role in translating these diverse voices into the context of schooling, pointing the way for society in general. Acknowledging these possibilities allows for cautionary tales about our individual lives. As we share these fragmented stories, it becomes possible for teachers to knit these together like a quilt instead of a grand narrative. Every patch is important and exists in relation to the next.

If we truly want coherence we must recognise this *border* as both an epistemological and metaphysical concept. One way of beginning such a realisation is to acknowledge the importance of cultural narratives. So where does that take us? Educational praxis is decentred and fractured, caught in a gap between modernism and postmodernism. One way of constructing meaning in this paradigm is to as-if the present. This entails acknowledging the multiple voices in our daily lives as teachers and learners and also as citizens in this not-so-brave new world.

COMPLEXITY

If coherence is elusive to many of our students in an empirical sense, does this suggest a sort of chaos and complexity that some postmodernists suggest? This is a serious issue. Relativism, chaos, and complexity arise as challenges to any coherent discourse because of our cultural narrations, our cautionary tales, and our attempts to share discourse. As we acknowledge different views and their multiple representations we make it more and more difficult to form coherence and act as-if we are part of a collective. This is the epistemological dilemma education faces.

Let's try to reframe this by suggesting that the diverse voices of our classroom create tensions and struggles as multiple discourses collide. These collisions happen for us in our classrooms but they also happen on an on-going basis outside of school. It is here in the roadways of our world that the connection really lies between the discourse of the classroom and the discourse of the street.

Clearly there are real boundaries here, but we should be able to express them in explicit, informal discourse. Significations aren't always easily read. Our inability to decode or even see the need to decode can get us into trouble in many ways. It sometimes takes an explicit statement like, "you don't want to associate with people like me," to stop a conversation in its tracks and force individuals to see what they had not been able to perceive and to attend to another form of discourse. This happens on the streets and it also occurs in school. These are the borders that are porous and permeable.

In the world of praxis, the boundaries are blurred, fused, or bleed into one another. Differences in discourse are distinct but not separate. There is another lens at play as well, the interpretive lens. This lens is like Superman's vision; with it you can see right through what some might label as "what this really means."

Pratt (1992) was also interested in social spaces, specifically the spaces created when different languages and cultures clash. She did not speak directly of the context of teaching and learning, but rather of a context that runs deep and parallel to our lives as teachers and learners, the "contexts of highly asymmetrical relations of power, such as colonialism, slavery, or their aftermaths as they are lived out in many parts of the world today" (p. 584). Does this sound like something Foucault might say? We need to think of our schools as institutions created by an ideological discourse, not an ideological discourse. By suggesting that there may be similarities in an epistemological approach to the study of various social structures, does not make them the same, but it does inform us of possibilities.

Another reason we can re-imagine the world of teaching and learning is that teachers and learners are challenging the meaning of the word "expert." Said (1994) said that the idea of expert implies that a privileged few define control and competence. In this modern/postmodern world we are rejecting that ideas and concepts "belong" or are owned by particular groups. Together we move in and out of coherence to chaos and complexity, and then we attempt to stitch it together so we can understand. Coherence and complexity take on new and diverse meaning. As we reject a "drift" towards consolidated power and authority we embrace individual liminal voices, often because we have to. How else can we uncover understanding? In short, we are setting sail from our safe harbors without a map but with a purpose. This can be dangerous. We need our theory and our practice. We also need the past read critically. And, as Anyon (2005) told us, we "need to unite, and acknowledge that the problems can be best resolved if they are tackled as intimately interrelated issues" (p. 175).

Doll's (1993) work reminded us that both contingency and uncertainty play important roles in the way that we draw lines of difference. As our world shifts in seemingly chaotic ways, the manner in which boundaries are drawn and how permeable they are is under constant review. For example, what counts as being a gifted student or a student at-risk? Any serious answer to this question can't be a simple quantitative response because the question is rooted in the dual perceptions of the teacher and the learner. This can, and often does, lead to conflicting borderlines that challenge our views. The question is: What do we do about it? Are we trapped in a paradigm of opposing extremes?

Fleener (2003), likewise, urged us to look at the role of complexity in teaching and learning. She called on us to reject the Tyler rationale, a process of fitting specific solutions to isolated problems, and to embrace our complexity. Fleener introduced us to "new science," a term he uses to collectively reference "the techniques and explorations of complex adaptive systems theory, the theory of dissipative structures, or chaos theory" (p. 2). Our emerging cultural narrations serve as examples of a system that is recursive, iterative, nonlinear, and complex. A challenge to the epistemologies of modern science might be found in a conversation on new science, thereby making explicit the multiplicity of nonlinear systems.

Kincheloe and Steinberg (1997) suggested that one way we can address complexity in our instruction is by expanding our range of literature and methodologies, thereby opening our students' minds to voices that have thus far remained unheard: "Researchers come to understand the multiple influences shaping their daunting task as they bring previously excluded people and categories of people into the process" (p. 47).

For mavericks, creativity is multi-dimensional and experiential, and yet we make scant use of the talents of mavericks inside or outside our schools. In textured, innovative settings the maverick nature can flourish when opportunities are tied to identity, complexity, and discourse. These sites highlight what is possible when experiences are provided that capture the imagination and take advantage of the natural curiosity of learners with different skill sets. A research project that provided elementary students with opportunities to think, talk, and write like philosophers illustrated how learners need experiences that are fragmentary, associative, and experimental and the freedom to wander into terra incognita.

AN EXAMPLE: PHILOSOPHICAL CONVERSATION

Simply put, philosophical conversation involves students making claims and supporting them as well as questioning one's views and the views of others. Philosophical topics are used to initiate the conversation, as the questions they invite have no right answer. *Doing* philosophy in this context means the students engage in a type of discussion in which open-ended questions about controversial topics in texts encourages children to take positions in response to the questions and identify reasons to support their positions.

Advocating for a community of inquiry model for guiding discussion, Lipman (2003) argued that through this model there is a conversion of the classroom into a place where “students listen to one another with respect, build on one another’s ideas, challenge one another to supply reasons for otherwise unsupported opinions, assist each other in drawing inferences from what has been said, and seek to identify one another’s assumptions” (p. 10). A community of inquiry leads to participants “questioning, reasoning, connecting, deliberating, challenging, and developing problem-solving techniques” (p. 14).

Philosophical conversation has similarities to other recent types of discussion which encourage students to justify their claims, including *accountable talk* (Michaels, O’Connor, & Resnick, 2007). Also referred to as reasoned discourse, deliberative discourse, and academically productive classroom talk, the features of this style of classroom discourse are accountability to the learning community, accountability to standards of reasoning, and accountability to knowledge.

Viewed by Lipman (2003) as a process, he argued critical thinking is “thinking that facilitates judgment because it (1) relies on criteria, (2) is self-correcting, and is (3) sensitive to context” (p. 116). The critical thinking component of engagement in a community of inquiry occurs when children examine their own arguments and others’ arguments during discussion. In Griffith’s (2009) call for reflective practitioners and practice, he suggested ways meaning could be measured dialogically, providing “evidence of students thinking critically and creatively” (p. 73).

Critical thinking involves the evaluation of knowledge claims. As described by Ennis (2003), critical thinking is “reasonable reflective thinking focused on deciding what to believe or do” (p. 97). Paul (1993) characterised it as “the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesyzing, and/or evaluating information gathered from, or generated by observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (p. 22). Ketch (2005) found that students put into practice particular higher-level thinking skills when they synthesise information from text with their ideas and the ideas of others. He argued that “the oral process helps students clarify and solidify their thoughts. The thinking changes from what it was before the conversation took place” (p. 9). This conception characterises critical thinking as a skill that can be taught and that a change in student thinking is evidence of critical thinking.

Thinking Critically About Texts

Examination of how the opportunities for learning philosophical conversation were consequential to students’ thinking and learning over time was the focus of a year-long ethnographic study (Skinner, 2012). Philosophy club members, twenty fourth-grade students and their teacher, met for one hour after school, once a week, September-May, at a Title I school in South Texas. Data for this study were analysed in relation to the classroom studied, its members, and their participation. Through examination of the discursive actions and interactions of the participants, patterns of interaction in student-to-student and teacher-to-student discourse were located to identify the learning opportunities constructed and appropriated by members of the group.

The structure, space, and text of the philosophy club provided participants opportunities to think critically about and discuss "talkworthy" (Sibberson, 2003) texts. These texts "draw us in and invite us to uncover a deeper meaning and to build our own unique understanding" (p. 60). The teacher's use of texts containing controversial topics to promote critical thinking and student discussion is supported by the work of scholars who have studied personal meaning as related to schooling (e.g., Rose & Griffith, 2003). Their findings illustrated that understanding and interpretation of meaning are related to connections between and to one's experience.

Analyses of ethnographic data revealed that time and space for critical thinking were provided in this context and the teacher prompted the students to give reasons for their beliefs. The investigation showed that given the opportunity, children can learn to think about text in new ways. Critical thinking involves the evaluation of knowledge claims. Findings from analysis of the discourse illustrated that students participating in the philosophy club evaluated others' claims in relation to their own over time. In and through conversations about texts, students accessed the opportunity to build on each others' beliefs and over time learned to articulate reasons for their own beliefs without prompting.

Another characteristic of critical thinking is the willingness and ability to analyse the views of others and change your own views in light of new evidence. Findings demonstrated that one student clearly reformulated her position on a topic after considering others' viewpoints when she proclaimed in the last session, "now I kind of disagree with myself." Her unique response indicated she was able to think critically about others' perspectives and change her own views after consideration of the arguments of others. The study revealed that change can be seen in student learning outcomes when students are provided access to distinctive ways of talking and thinking about text.

Reformulating Roles and Relationships

Following Bruner (2004), philosophical conversation can be viewed as a genre, since a "genre commits one to use language in a certain way" (p. 692). The discourse format of philosophical conversation was a new genre for the teacher and students in the philosophy club. Participation and empowerment were two of the students' rights in the philosophy club, bestowed on the students by the teacher on the first day. The students were given the right and the responsibility to maintain autonomous control of the discussion; they were free to keep the discussion going without intervention from the teacher.

The roles and relationships of group members in a classroom are fluid as members of the group negotiate and renegotiate those roles and relationships discursively and interactionally. When the teacher in the philosophy club released the authority for the discussion to the students, the students had both the right and the responsibility to choose the direction of the conversation from the outset. The discursive interactions entailed in the enactment of this attempt by the teacher to empower the students from the beginning made visible the ways in which the students undertook the role of discussion leader in and across time.

Several students in the philosophy club discursively asserted their newly-given authority in ways expected and in ways beyond what was anticipated by the teacher. An examination of the student talk during the discussions revealed that various students successfully enacted many of the practices common for a teacher leading a group discussion, specifically, controlling the floor, assigning turns of talk, initiating questions and making connections to prior knowledge, changing the topic of discussion, and evaluating students' responses. The accomplishment of the practices of a discussion leader by several individuals demonstrated that the collective recognised the authority of individuals-within-collective besides the teacher to direct the discussion.

Increased participation is increased power and several of the students in the club accessed the given power. Evidence of the students' take-up of power in the philosophy club over time were: the relatively constant number of students in attendance over time, the length and quantity of the chains of student interaction, the student's influence on topics of discussion, and individual student's influence on current and future activities available to the group.

Interestingly, while the students accessed power over speaking rights and control of the topics of conversation, they never fully accomplished autonomy of either. Collectively, the students increased their turns and talks and chains of interaction without interference from the teacher over time and across sessions. The teacher, however, continued to interject in the students' conversations, not for the purpose of questioning students about support for their claims, but often to nominate a student to speak. Not all of the students assumed the authority given and those students were not the only participants who had difficulty changing established participation patterns of discussion.

Comparison of the teacher's discursive patterns over time revealed the teacher nominated a student to speak multiple times during every discussion. Sometimes the nomination was requested by the student through discourse or actions, but other times the teacher chose who would speak next for reasons she related to fairness or inclusion. The inability of the teacher and many of the students to ever extinguish the practice of teacher nomination of turns highlights the difficulty that participants in a school setting have completely reformulating the roles of teacher and student.

In the philosophy club, many of the roles exclusively reserved for *teacher* or *student* were shared by all participants. For example, the traditional teacher roles of rule maker, idea builder, interrogator, and meaning confirmer were accessed by the students as well as the teacher during the discussion. The teacher manipulated the physical and social environment of the class to make it conducive to learning the new type of discussion. The teacher's role remained central, she controlled the selection of the text, when it would be accessed, and sometimes, by whom. The teacher was the only participant who prompted other participants to build on their ideas or to address others in the group. The students did share the traditional role of evaluator of the discourse and also enforcer of the rules of philosophical conversation.

This analysis supported the view that people in a class assume a variety of roles (Collins & Green, 1992) and these roles extend beyond the traditionally defined roles of teacher and student to include positions members of the group assume related to the particular action or activity in which the member is engaged. Davies and Harre (1990) argued that positioning of oneself can be accepted or questioned by others in discursive interaction. If it is unquestioned, then the related positions are considered a norm of the discussants' culture.

As other studies have indicated, the nature of the discourse in classrooms influences what opportunities for learning are available to the students as well as the knowledge that is created and shared (e.g., Mercer & Hodgkinson, 2008). Analyses of the students' discourse over time also support ethnographic work in K-12 classroom settings that showed how "what is constructed in one event is consequential for what students are able to know, do and understand in subsequent points in time" (Castanheira, Crawford, Dixon, & Green, 2000, p. 353). In one particular session in the middle of the year, a very controversial text sparked a conversation unlike any other the students had previously engaged in. This was illustrated by an exchange between two students near the end of that particular conversation. Lonnie appealed to the teacher to intervene in the argumentative discussion with "all these conversations/ are confusing me/I just want/to get/to the point." Emerald agreed, "yeah/this is the longest conversation/ we've had/and it's kind of like/we're fighting/ some are agreeing/ and some are disagreeing." From this point on, the students would discuss topics in longer chains of interaction and would build on one another's ideas with a mixture of agreement about and disagreement over viewpoints. The building of ideas by students was also evidence that the students listened to each other during the discussions.

Discourse practices in the classroom involve both the teacher and the learners in a shared endeavor of meaning-making. Cazden (2001) argued that spoken language "is the medium by which much teaching takes place and in which students demonstrate to teachers much of what they know" (p. 432). The children who participated in this new learning environment created a membership in a particular discourse community with a distinct language and culture. This experience provided the students other ways to think about, talk about, and explore learning (e.g., Green & Dixon, 1993; Kumpulainen et al., 2009).

Learning is first and foremost the result of opportunity. In this after-school educational space, opportunities were located that influenced student learning by identifying what was adopted, appropriated, or adapted by all, some, or one of the students. This is not to say that all students learned when each particular opportunity was taken up, but rather that learning outcomes changed for one or more participants.

By focusing on the learning opportunities constructed and adopted in this learning community, this study made visible the developing and shifting nature of student learning and participation as members of the philosophy club. Findings also revealed how elementary-age children over the course of the year-long after-school program changed their ways of thinking with texts, understanding self, and acting in their local, social worlds. This examination of local constructions of knowledge over time illustrated the ways in which those constructions are consequential for teacher and student learning. This project provides an example of how teachers can reformulate relationships between teaching and learning in school settings.

FINAL THOUGHTS

We live immersed in what appears to be paradox between coherence and complexity, as well as between authority and cultural narratives. It is the gap between the modern presuppositions we largely live by and the emerging presuppositions we are testing that makes this seem chaotic. It is the pull of the individual and the collective and their multi-layered discourses. Our cultural narrations have defined our place, yet within this collective are the multiple representations found in the multi-textualities of media and technology. It may be an absolute presupposition about western civilisation that we search for order and create it when it doesn't exist. If that is the case, this is the opportunity of a lifetime. Coherence, complexity, and reflexion form a dynamic trialectic and afford us possibilities to consider in this epistemological gap. These liminal new learners are a generation of students who are hopeful, hardworking, innovative, and imaginative. To help this generation realise their potential, we must fuse teaching and learning by acknowledging, listening, and critically attending to these merging possibilities.

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JEFFREY W. BLOOM

COMPLEXITY, PATTERNS, AND CREATIVITY

The title of this chapter suggests three distinct yet tightly intertwined ideas of complexity, patterns, and creativity. These ideas have been deeply embedded and intertwined patterns throughout my teaching and academic career. As Catherine Bateson (1995) has described them, these ideas have become major thematic helical patterns that have submerged and re-emerged for many decades. I relate this brief personal history not so much as a description of my background, but as a description of complexity, patterns, and creativity themselves. These three themes became part of my set of complex systems of learning. In this chapter, I explore the dynamics of these and related ideas in the contexts of teaching, learning, and thinking. However, these ideas of complexity, patterns, and creativity are examined by aligning them to a context of natural systems. Gregory Bateson (Bateson, G., 1979/2002; Bateson, N., 2011) maintained that we have to examine how our thinking can be aligned with how the natural world works. At this point, we have reached a point where our thinking has diverged from the way nature works, which has led to dire consequences. As human beings, we have the capability to think in ways that are destructive to ourselves and to our environments. Yet, we are biological beings that have arisen through evolutionary processes. In many if not most traditional tribal societies, people thought and lived in ways that were not self-destructive or destructive to their environments (Maybury-Lewis, 1992). There is no room here to explore the history of this divergence in human thinking. However, this idea of the connection between biological patterns and human cognitive patterns is a theme we need to keep in mind as we explore complexity, patterns, and creativity.

CREATIVITY

For most creativity researchers, the focus on creativity as a subject to study began quite recently. However, many Western philosophers dating back to Plato have explored creativity. Plato (-347 BCE/2007) spent significant time discussing creativity (for which there was no Greek word) in terms of poetry and poets. Interestingly, the Greek word for poetry is poiesis or "making," which is the root of the word that describes one of the key features of complex systems: autopoiesis or self-making that has been expanded to include concepts such as self-generating, self-organising, self-regulating, self-maintaining, self-transcending, and so forth (Capra, 1996).

Contemporary interest in creativity as a subject of investigation began in the middle of the 20th Century as our enthrallment with positivist and behaviourist approaches

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 199–214.

to understanding our world began to wane. Although much of Guilford's (1950, 1967) work was behaviourist and positivist in nature, he may have been the first contemporary psychologist to examine seriously the nature of creativity. He, along with Meeker (1969), who applied his work to education, may have been the first to distinguish between convergent and divergent thinking in creativity (Spendlove, 2012). Certainly, these two cognitive processes of production are consistent with the biological patterns of convergent and divergent evolution. During this same period of time, Koestler (1964/1969, 1967) stood out as another investigator of creativity, not just as a cognitive activity, but as part of larger patterns of living systems.

Since the 1950's, creativity research focused on ways of (a) measuring creativity, such as the Torrance Test of Creativity (1974) I used in my early days of teaching, (b) dissecting and categorising creativity, (c) discriminating between creativity as an acquired trait or as a genetic trait, and (d) exploring creativity as a cognitive tool for specific benefits, all of which are reviewed by Spendlove (2012). Although interesting, much of this work was embedded in positivist, reductionist, mechanist, utilitarian, and determinist assumptions. Even the ideas in the "underground book," *Synectics* (Gordon, 1961), that was popular in my college days was embedded in such assumptions that are still influential. I do not want to dismiss such work, which has extended our understanding in both depth and extent. However, I do think we need to keep in mind this history and its influence. Throughout the rest of this chapter, I will be setting up the context for a perspective of creativity that is situated in the complex biological systems of which we are part.

COMPLEXITY AND COMPLEX SYSTEMS

Our everyday use of the word *complexity* does not mean the same thing as "complexity" in the context of complex systems. We often use "complexity" interchangeably with "complicated," but within the context of systems it may or may not be complicated. Fundamentally, complexity describes the nature of systems that are autopoietic (Maturana & Varela, 1998). In other words, complexity describes the ways in which various systems maintain some degree of continuity. As living organisms, each one of us is a complex system. Our bodies maintain themselves for relatively long periods of time, hopefully. Our cognitive and creative capacities are part of this complex system as well. In fact, our survival as individuals and as a species is dependent upon our cognition. At the same time, human beings are part of even larger complex systems such as various social groupings, cultures, ecosystems, and the biosphere as a whole. Fundamentally, we live in a world of systems within systems and of interacting systems and sets of systems.

For a complex system to function in ways that allow the system to survive and thrive, there are *patterns of organisation* or networks of non-linear pathways and feedback loops through which information and materials flow. These are the autopoietic processes. In the human body, an example of a *complex structure*, our neural pathways, lymphatic systems, circulatory systems, RNA molecules, hormones, and other substances as well as many of the organisms that live on and within our bodies all function to help maintain the system as a whole. These patterns of organisation and complex structures are generated and maintained by *processes of production* that require some sort of energy production and storage such as photosynthesis and cellular respiration where energy is stored and utilised in the binary of ADP—ATP or adenosine diphosphate—adenosine triphosphate. Although cognitive systems still require the biochemical energy to function, they also require emotional energy, passion, or curiosity to function. While the biological functions of the system operate in relationship to one another, our whole beings are more than just our bodies. The self-transcendent quality of such a complex system creates a whole that is greater than just all of the parts working together. Even a simple mechanical system, such as a bicycle, can become a part of a larger complex system as the bike and rider interact. The bike becomes more than just a mechanical system. It becomes part of the rider's identity in the social and cultural context in which he or she rides. A cyclist in the United States may have a very different bike-rider identity from the bike-rider in a village in India.

Such an idea of a system that goes beyond the rider to the bike suggests a notion of mind that extends beyond the skull and even the body. The concept that mind is more than what exists in the human skull was proposed by early Buddhists (Sangharakshita, 1957; Nisker, 1998) and Western philosophers as early as Anaxagoras in the early 400's BCE (Russell, 1945) and more recently by phenomenologists (Hegel, 1910) and others (e.g., Bertrand Russell). However, in the beginning of cybernetics during the late 1940's and early 1950's, Gregory Bateson (1972/2000) formulated a cybernetics explanation of how mind transcended the limitations of the biological body. For Bateson, mind was a cybernetic system of information flow and feedback loops. From this perspective, our interactions with the contexts within which we live are part of the information flow. For instance, as we drive a car, we respond to a variety of sensory information from the steering wheel, the seat, the brake pedal, the accelerator pedal, various sounds, and the visual field. This information comes from the car, the road, and from objects and events in the surrounding context. We respond to this information by moving the steering wheel, stepping on the brake, or pushing on the accelerator. In turn, that information flows back to the brake pads, wheels, engine, and so forth. With any luck, we manage to move around without getting into an accident or getting a traffic ticket, both of which also are extensions of the information pathways. Viewing mind as extending beyond the individual is critical to understanding the power of context and social interactions in thinking and creativity as suggested by the thinking and behaviour of bats and meerkats (Perony, 2013).

As human beings, one of the major problems we face is that we do not see ourselves as complex systems or as parts of even greater complex systems. We reduce ourselves to isolated individual "things" with no real connection to anything else. From that point of view, we can give the finger to someone else, dump toxic waste into the environment, over-fish a lake or ocean, and bomb other cultures without seeing the consequences for the well-being of ourselves, of others, and of the very environments of which we are a part. The same basic idea holds true for classrooms and schools. The politics of schooling perpetuates a fundamental pathology in the systems of classrooms and schools that isolate and disconnect students and teachers. As the focus shifts to specific content acquisition (which in itself is decontextualised and sanitised) and to conformity in approaches to teaching and learning, we further disconnect children and teachers from themselves, one another, their biological and physical contexts, and the world of ideas.

THE IMPORTANCE OF DIVERSITY IN COMPLEX SYSTEMS

The approaches of schooling and society value ideas of conformity and devalue the notion of diversity that serves to isolate, fragment, and disconnect knowledge. Such approaches and ideas are dangerous. The biosphere and its ecosystems, the survival and continuity of species, evolutionary speciation, and the welfare of societies and cultures are dependent upon diversity or variation. Gregory Bateson (1972/2000, 1979/2002) maintained that the diversity of ideas was essential. His notion of *idea* as information extended from that of mental construction to that of a DNA sequence. From such a perspective, the dualistic separation of mind and body and of *us* from our environment is artificial. The patterns of ideas and this broader perspective of mind and cognition operate in similar ways across contexts and levels of scale. In all cases, creativity is evident when ideas interact, change, and give rise to new ideas. Without diversity, the emergence of new *ideas*, new forms, new species is greatly limited. Without diversity, adapting and adjusting to new conditions are hindered or prevented. Without diversity, complex systems have no material for change.

Bateson (1972/2000, 1979/2002, 1991) suggested that the essential or core characteristic of diversity is *difference.* In fact, difference is the unit of mind. Building on Korzybski's idea that the "map is not the territory," Bateson (1972/2000) suggested that nothing will appear on the map if there is no difference (p. 455). In this argument, the territory may be considered the world in which we live, while the map is comprised of our mental representations of this world. My idea of a bicycle is not the bicycle. My idea of a cup of coffee is not the cup of coffee as suggested by Keanini (Bateson, N., 2011). So, the idea of difference suggests that if there is no difference, we cannot even perceive some *thing* in order to create a representation or our idea of some other *idea*.

Last year, I had an MRI of my head. The difference between lying outside of the MRI tube to lying inside the tube was dramatic. My initial reaction to moving from a visual field of differences to a visual field of no differences was one of claustrophobia. I had no sense of how far away anything was from my head. I was in a white field with no differences. Although there was a difference between in and out, the *in* situation was disorienting. As Bateson would have suggested, there was no news of difference.

Without a fundamental difference – from nothing to something or from one to two or more *things* – there is nothing. As we expand the differences, a world based on diversity is created. Simple and complex systems require difference and diversity. A particular situation comprised of differences makes up a context of some sort. A classroom is comprised of some structural situation that could be a forest for an outdoor *classroom* to a human-made *box* with four walls, a floor, and a ceiling. Inside the classroom, there are various other *things* (like desks, tables, chairs) and people. This physical context can be fairly limited and simplistic to more elaborate and complicated. The context also can include the individual, social, and cultural variation among students as well as the philosophical manifestations of the teacher and his or her approach to teaching and learning. A teacher-controlled classroom management approach creates a different context than a classroom community based on distributed and shared control. The teacher-controlled context tends to be like a simple, mechanical system that verges on collapse while trying to maintain conformity and minimise difference. Whereas, the distributed control approach is more of a complex system that adjusts to variation and, in fact, requires difference and variation to thrive. At the same time, "differences are the things that get onto a map" (Bateson, G., 1972/2000, p. 457) or get into cognitive representations.

The fabric of a world of difference and diversity is relationship. Everything is in relationship to something else. In Nora Bateson's film (2011), Gregory Bateson contends that we "live in a world that's only made of relationships," which suggests that a world made of differences is a world made of relationships among these differences. A tree is comprised of relationships, such as a cell in the phloem is in sets of relationships to other cells in the phloem, in the roots, and in the leaves. The function of the phloem is based on binaries of high-low pressure and high-low concentrations of sugar. These binaries draw the food (sugar) across cell membranes and throughout the tree and its roots. The xylem or tubes that transport water and minerals up from the roots to the leaves are driven by the evaporation of water from the stomata or pores on the under-surface of leaves. Furthermore, the tree does not exist in isolation but in relationship to other trees, plants, bacteria, fungi, animals, protists, human beings, industries, pollution, and so forth.

RELATIONSHIPS AND SYSTEMS

At this point in the discussion, we have some sense that difference, diversity or variation, relationship, and context are essential to understanding how complex systems function, while pointing to the basis for how creativity manifests in complex systems. However, we also need to develop an understanding of the nature and dynamics of relationships. Although the previous discussion treated systems as being comprised of relationships, many if not most relationships themselves are systems (Bloom, 2012b). The flow and exchange of information and/or materials occur within systems, much as they do between those *things* or beings within a relationship. In fact, as Kelso and Engstrøm (2006) suggest, nothing happens without two or more *things* interacting in some sort of relationship. The work of Kelso and Engstrøm focuses on coordination dynamics across scales of relationship between what they refer to as complementary pairs in brain function, an expanded sense of mind, and well beyond to the fundamental nature of the universe.

Everything arises out of relational dynamics. From an earlier study of children's discourse (Bloom, 2001), in which I examined an argument about density through the lens of complex systems, I began to suspect that not only did all arguments arise out of conflicting binaries, but that all systems are initiated and maintained by tensions within various types of binaries. Bateson identified three fundamental types of relationships that describe and address relational tensions in different ways. Complementary relationships are offset pairings that are oppositional. Examples of complementary relationships include dominant-submissive, leader-follower, strong-weak, and outgoing-withdrawn. Symmetrical relationships tend to be equivalent pairings such as dominant-dominant and follower-follower. Dominant-dominant relationships are characterised by competition. In the follower-follower case, the relationships have difficulties functioning. In contemporary western societies, both complementary and symmetrical relationships are difficult to maintain over time. They often descend into conflict and resentment or into dysfunction. However, there are situations where such relationships are necessary. Law enforcement, the military, fire and rescue operations, and people in emergency situations need to work within complementary relationships where someone has to be in control and others need to follow. In other situations, it may be beneficial to be in a symmetrical relationship, at least momentarily, such as competing in some athletic event. Engaging in an argument may be necessary to develop deeper understandings and make any kind of meaningful gain in knowledge or a relationship. However, the third type, reciprocal relationship, is characterised by negotiation and compromise. These relationships tend to be durable. Although such relationships may become complementary or symmetrical from time to time, they return to reciprocity (Bateson, G., 1972/2000).

On the other hand, some relationships are intensely problematic. In such cases, the messages of one type of relationship are permeated with conflicting messages. In the 1950's, Gregory Bateson along with his colleagues Jackson, Haley, and Weakland developed the idea of double bind to explain certain dysfunctional traps in interactions and communications in certain relationships (a report in a 1956 issue of *Behavioral Science* is reprinted in *Steps to an Ecology of Mind*, 1972/2000). The double bind is a binary trap, where there appears to be no viable alternative or answer to a specific situation. A simple double bind may consist of an animal running from a forest fire. When this animal comes to a cliff, it is faced with the alternative to go over the cliff, in which case there is a high likelihood of dying, or to stay at the cliff's edge, in which case there also is a high likelihood of dying. We all face decisions like this, but usually not as dire. However, more intensive double binds not only involve specific traps in interaction or communication, but also are embedded in contexts that support and promote double binds.

A parent who continually treats and communicates with his or her child with double binding actions and communications creates such a problematic context. The parent may tell the child not to do something, but when the child tries to do the right thing, he or she is reprimanded. The parent may even say to the child that some action is "okay," but the body language and actions may contradict what is said. And, when a child comes home late from school or from playing with friends and confronted with double binding questions, such as: "Why are you always coming home late?"—there is no room for a "correct" response. The question recipient is wrong no matter what response is offered. As difficult to deal with as double binds are, they do provide opportunities for transcending the context and responding with creative solutions (Bateson, M. C., 2005; Gibney, 2006). There are no formulas for creative solutions to double binds or creative solutions of any kind. However, the sense here is that potential solutions cannot arise from the double binding context, but can arise from transcending the contextual rules or from jumping across contextual boundaries.

PATTERNS

The fundamental organisation of just about everything involves patterns. From the binary attractions within atoms to the ways living things are organised and function to vast galaxies and to mind and culture, patterns underlie, comprise, and connect every *thing*. Within complexity theories, patterns of organisation are ubiquitous and permeate all aspects of our world including actual forms, processes across scales and dimensions, manifestations of mind and culture, and metaphors (Ball, 2011a, 2011b, 2011c; Bloom, 2004; Bloom & Volk, 2007; Bloom & Volk, 2012; Bloom, Volk, & Richards, 2007; Volk, 1995; Volk & Bloom, 2007; Wilber, 1995). In fact, patterns also characterise the processes of production and the structures of systems. Returning to the previous discussion of relationships, patterns are the manifestations or expressions of relationship.

Gregory Bateson (1979/2002) coined the term *metapatterns* as a way to capture the power and scope of patterns including his ultimate question that he posed for others to find the "pattern which connects." The question: "What is the pattern which connects?" was not meant to be answered definitively but was meant to be a stimulus for a continual quest for understanding the connectedness of everything (Bateson, N., 2011). The prefix "meta" in metapatterns suggests such an overarching or higher level of pattern or of a pattern of patterns. In 1995 while trying to describe a number of specific functional metapatterns that arise from evolution, Volk examined Bateson's idea of metapatterns. These specific patterns include (a) specific forms or shapes, such as sheets, tubes, and spheres; (b) organisational elaborations, such as various layers of form and function, centres, binaries as the beginning of complex sets of relationships, and borders with regulating pores; and (c) temporal patterns of relationship, such as breaks (branches and transformations), arrows, calendars, and cycles. Volk's work is specifically connected to the work of Bateson.

However, for over a century a number of people have explored the importance of various patterns and their functions, including Thompson's (1942/1972) ground-breaking examination of the physics of biological form and function, Carroll's (2005) extended examination of forms in evolution, Stevens' (1974) examination of universal patterns in nature, McHarg's (1969/1971) examination of urban design that is consistent with patterns in nature, Kapparoff's (1991) mathematical exploration of patterns as connections, Wilbur's (1995) spiritual and scientific exploration of universal patterns, Campbell's (1972/1993) examination of myths as patterns of culture; Lakoff and Johnson's (1980) explorations of metaphoric patterns in mind and culture, and Barabási's (2010) explorations of networks and bursts as fundamental patterns. Coward's (1990) seminal work in pattern thinking has extended our understanding of cognition as a pattern-based process. Although interest in and understandings of patterns and metapatterns have increased, as any Internet search will show, patterns as a serious domain has not taken hold in schooling, cognitive studies, and many other contexts.

The power and scope of patterns are significant. For instance, binaries, which are the beginnings of complex relationships, appear to be the basis of the universe. Pairs of eyes, nostrils, ears, and legs or sets of legs not only are the expression of bilateral symmetry, but also are functionally significant. One eye, nostril, or ear is not particularly useful for survival. However, two of these organs provide an exponential leap in their advantages. However, three or four are not significantly more helpful, especially considering the energy and material "costs" to produce more than two. The binary of positive-negative atomic forces along with the predominantly ignored issue of attraction-repulsion (why electrons do not collapse into the proton) is the very building block of the material universe. Binaries are just another way of discussing relationships. We can extend this view of relational binaries to other patterns. A border is a binary of in-out. A tube is a binary of directional flow while an arrow is a binary of directionality. Binaries and sets of binaries tend to drive cycles, such as with evaporation-precipitation in the water cycle.

Pattern thinking is part of the built-in capacity of various cognitive systems, including those of human beings (Coward, 1990). We recognise patterns and use patterns to make sense of our perceptions. However, we do little to promote and develop this capacity throughout schooling. In part, this may be due to our limited view and understandings of patterns and how this capacity can be used in learning, analysing, designing, and creating. We are made of patterns that have emerged divergently and convergently throughout biological evolution. We think in patterns that have roots in these same evolutionary processes. We create cultural and technological constructs based on these same patterns (Volk, 1995; Volk & Bloom, 2007). In fact, the entire physical world is constructed on physical principles that involve these very same patterns (Kappraff, 1991; Stevens, 1974; Volk, 2013).

Thinking in patterns can provide us with cognitive tools to develop deeper and more complicated *understandings* of our world that actually tap into the very complex nature of multiple interacting systems (Bloom, 2004, 2012a, 2013;

Bloom & Volk, 2007, 2012). For example, we can examine an earthworm as being comprised of a number of interconnected, functional patterns. They are tubes within tubes as layers of functionality. As tubes, earthworms can penetrate the soil, transport materials and information from one end to the other, and separate the functions of various tubes as holons or layers of functionality—such as the digestive tract, nervous system, circulatory system, and muscles. The tube within a tube design allows distribution of functionality much in the same way the human body is designed as tubes within tubes. Earthworms utilise a binary of muscles for movement with a secondary effect on circulation. Each individual contains a binary of sexes with pores connected to tubes and spheres of sex organs. They move and maintain their individual survival through complex systems of non-linear cycles at various levels of scale. The same functional patterns exist in all life forms. We can continue with other specific earthworm patterns, but this treatment is just an example of how functional patterns both comprise an individual organism and share functional patterns across organisms and beyond such as the tubes-within-tubes structures of communication wires, computer circuitry, highways and tunnels, ship and airplane construction. Then beyond the individual organism, we can find cycles of reproduction or replication for maintaining the continuity of the species much in the same ways that cycles of information exchange maintain the continuity of cultures. In addition, the patterns of earthworm life and survival in individuals and species interact with the survival of ecosystems, like that of gardens and agricultural systems. But, rather than investigate such sets of interacting patterns and systems in schooling, we reduce *learning* to discrete, disconnected bits of information.

Pattern thinking also can be used for the *analysis* of systems, situations, objects, and events (Bloom, 2004, 2012a, 2013; Bloom & Volk, 2007, 2012). As with the earthworm example we can zoom in to look at parts of more complicated objects or events, then zoom out while examining scales of interactions among the parts up to actions of the whole and then up to interactions among different wholes. We can examine a government as a holon (a whole functional layer) comprised of clonons (individuals within the government) but also see how governments become hierarchical layers that set up a variety of binaries or relationships, some of which can become quite pathological in terms of binary-based double binds and complementary and symmetrical power relations. We can delve even further into the nature of these patterns of relationships by looking at the arrows and webs or networks that describe power structures and the hegemony of particular contexts.

We also can use patterns and pattern thinking for *design* (Bloom, 2004, 2012a, 2013; Bloom & Volk, 2007, 2012). Artists use these patterns all of the time by juxtaposing binaries of light and shadow and utilising various patterns of form. Musicians use cycles of repetitions of beat and cycles of sound frequencies within binaries of sound and silence. Such examples are endless as we explore all kinds of endeavors from those of scientists and mathematicians to those of writers and artists. We also can use such functional patterns in the design of various technologies and structures, as well as in the design of a classroom space and the functionality of a classroom community.

Pattern thinking recognises patterns, analyses their functions and meanings, analyses multiple perspectives, situates patterns in contexts, evaluates, models, organises, and categorises in ways that exemplify transcontextual and transdisciplinary thinking (Coward, 1990; Volk & Bloom, 2007). Pattern thinking also provides for creativity in insight and production. A significant aspect of this creativity lies in the nature of patterns as fundamental to our living and non-living worlds. However, the creative power lies in our ability to see and use patterns across disciplines and contexts. Peirce (Frankfurt, 1958; Burks, 1992; Kapitan, 1992) described this ability as abductive thinking, which became a significant way for Bateson (1972/2000, 1991) to describe rigor in ways that did not fall into the traps of measuring things that are not measureable. However, the ability to abduct or to use, apply, test, and explore how particular functional or metaphorical patterns connect across diverse contexts is a source of creativity. We can see examples of such abduction in the development of Velcro from de Mestral's "accidental" insight of his dog picking up burrs from a walk through a field in 1941 (Velcro, 2014) or the development of airplane wings from the patterns of structure in birds' wings. Poets, novelists, and artists borrow their insights from diverse contexts as well. At the same time, the evolution of various structures and processes have arisen from the various processes that are based in stochastic or random systems as well as what might be more directed creativity of the larger complex system (Margulis, 1998).

COMPLEX CREATIVITY

From within complex systems, creativity arises from non-linear pathways of information flow, diversity or variation, and the dynamics of relationships, including double binds. At the same time, creativity in complex systems relies on random or stochastic processes, as well as on processes that are more directly concerned with specific outcomes or problems. The patterns that arise or emerge from various processes and that are embedded in the systems are also critical components of creativity. In cognition, each of these characteristics and processes come into play along with our ability to think across contexts and disciplines.

In the biological world, emergence—the arising of something new—is creativity. However, as Wilber (1995) noted, emergence describes a process but does not explain anything. What is this creative process of emergence? A novel idea emerges. A new species arises. A groundbreaking technology is invented. A song is composed. A painting is completed. A poem is scratched out in a notebook. Each of these emergent objects is creative. In biology, a single-celled organism can divide into two clones of the original. A binary split occurs in much the same way as our skin cells split into two, then four, then eight, and so on. Unless some event occurs that modifies the DNA, such replication is not particularly creative. No new form or variation occurs. Although such non-creative replication is essential for survival, such as repairing damaged tissues or creating more individuals when in dire circumstances, the very foundation of life on Earth is based on the variation imbued in sexual binaries.

Random variation provides a source of genetic material that can lead to emergent new properties or species. As mentioned earlier, binaries seem to be essential for initiating and maintaining systems.

However, another source of creative emergence has to do with relationship binaries or symbiotic binaries, as suggested by Margulis (1998). In early evolutionary history, certain bacteria worked their way into single-celled organisms. Both organisms benefited, but after a while, the relationship became a permanent one. The bacteria lost much of their individuality, but played an important role in cellular physiology and energy production in what we now call mitochondria. Interestingly, the mitochondria still hold onto a certain degree of individuality in their own DNA. And, such individuality within the whole can now allow us to track maternal lineages passed on directly through the female mitochondrial DNA.

There are many other examples of relational binaries between wholes and parts of wholes that serve as sources of creativity, such as with John Lennon and Yoko Ono (Tracy, 2014) and with Patti Smith and Robert Mapplethorpe (Smith, 2010). The dynamics of these relationships created wholes that were larger than the individual parts. They also provided for the emergence of new forms of art, photography, poetry, and music. The creativity that arises from various relationships involves some sort of tension that sparks such creative emergence. These tensions may involve a variety of differences between the parts or may involve more intense double binding tensions. In either case, there is some sense of self-transcendence or transcontextuality that provides new perspectives and new pathways to creativity.

But what are the dynamics of binaries that lead to creativity? In Bateson's (1972/2000) three types of relationships – complementary, symmetrical, and reciprocal – there are particular tensions that are part of these relationships. In fact, these three categories are descriptive of the ways in which the tensions are addressed, rather than explanatory. Coordination dynamics may at least provide some insight into the nature of binaries. Kelso and Engstrøm (2006) suggest that oppositional pairings are necessary for the functioning of the human brain and of pretty much all living things. However, the way in which oppositional binaries coordinate is variable. Each system has its own rules, but they all involve non-linear, recursive patterns of information exchange. Pairs of "things" come together and move apart, then come together again in various ways. There is no steady state, which is characteristic of chaotic and complex systems. They always need to be far from equilibrium (Capra, 1996). If they are in equilibrium, they are most likely dead. Living systems are always in flux, and dealing with tensions of various kinds.

Bateson (1979/2002) described this flux in terms of cybernetic feedback loops that operate in ways that minimise, maximise, or optimise the conditions. For example, our body temperature operates in a way that optimises the conditions. At 35^{o} C or 98.6^{o} F, our physiology works in a way that does not maximise or minimise enzyme and other physiological activities or efficiency. If we get sick, our physiological systems raise the temperature in an effort to kill off the invaders. At 106^{o} F, our enzymes and those of the invading bacteria (at least that's the *hope*) are working at peak efficiency, but they decay rapidly. The idea is to kill off the invaders before you kill yourself. Such an approach is the body's version of chemotherapy. On the other hand, our bodies can minimise the temperature in an effort to save the system, as well. However, the same sort of save-or-die risk occurs. These sorts of non-linear information and control patterns occur throughout the biosphere and at all levels of scale. And, I am suggesting that creativity as a process involves these same patterns of non-linear information flow. However, how is creativity different from mere replication or repetition? Changing body temperature in an attempt to survive in and of itself is not creative. However, the initial evolutionary development of this ability was creative. Throughout our living world are examples of the results of evolutionary creativity. The use of the sheet metapattern for the development of wings was a creative leap. But, was the first use of wings or each separate introduction of wings also creative? Insect wings were developed separately from the wings of birds. The use of wing-like features on maple seeds is an entirely separate lineage of sheet usage. Was the development of planes and their use of wings a creative act?

At this point in my thinking, I believe such separate innovations are creative acts. They are leaps that transcend the initial situation. They may use existent patterns in new ways or combine sets of patterns to create new forms. In human creativity, these forms may be ideas, images, and insights. But, do they have to be useful as suggested by Robinson (2006) and others (Beghetto & Kaufman, 2007; Runco & Jaegar, 2012; Spendlove, 2012)? Throughout evolution, some emergent forms and species appeared but did not significantly add to the ability of an organism to survive. Were these creative acts? Maybe the emergence of these new forms was just poorly timed. Or, maybe the conditions changed too rapidly. In the same way, is a novel idea, image, or insight creative if it is never acted upon? If I generate a haiku in my head but never write it down or if I write it down, but never share it, is it creative? As autopoietic systems, pathways for creativity are built-in. These pathways allow for creative paths to self-transcend (as a specific aspect of creativity from Koestler's [1964/1969] work), self-maintain, self-generate, and self-regulate. Creativity does need to be useful, but maybe the patterns of creative generation without specific utility is just *practice*. We generate ideas to keep the pathways working.

Play is just this sort of practice. Young children move in and out of fantasy worlds and fantasy play in ways that are indicative of creative complexity. Such creative complexity is evident in the work of Paley (1990) and Singer, Golinkoff, and Hirsch-Pasek (2006). As children grow older, schools tend to suppress their creativity, but they find other outlets in various gaming worlds and other contexts. However, on occasion, teachers can provide fantasy worlds that replicate relevant and meaningful real-world contexts and issues. Such approaches can be powerful ways to encourage creativity in more relevant situations, as with Hunter's (2011, 2013) World Peace Game. In this game, 4th grade children tackle some of the most pressing problems facing humanity within a long-term simulation. Hunter refers to the outcomes of this game as moments of spontaneous wisdom and spontaneous acts of compassion that are not predictable. The children find themselves in double binds and other untenable situations but find creative solutions often by transcending the specific situation.

IMPLICATIONS AND DISCUSSION

Spend any time around young children and one is bound to see how boundless creativity is expressed in their talk and play as evident in my early studies of children's contexts of meanings (Bloom, 1990, 1992a, 1992b). They generate fantasy situations and characters. They make leaps across contexts and what we call subject matter disciplines. They see patterns and make connections in sometimes unusual and insightful ways. They are, in very important ways, using non-linear, autopoietic pathways of creativity. They are practicing the ways of thinking that could be beneficial for future thinking, problem-solving, and even survival. However, schools not only devalue these processes, they undermine them. Drill-and-practice, teaching-to-the-test, and other rote memory and superficial approaches to *learning* take the place of helping students develop and refine the very thinking processes that are part of their biological make-up. The Common Core has gone to the extent of emphasising reading and writing about content at the expense of reading fiction and creative writing. Block (1997) published a chilling examination of how schools promoted and enacted psychological violence against children. Block's critique was written before the Common Core Standards and before No Child Left Behind legislation. The scope of psychological violence has now been pushed far beyond what Block critiqued 17 years ago.

There are many approaches we can take in schools that can help foster creativity and creative thinking. We can engage children in inquiry where, with the help of teachers' they design investigations, collect data, formulate explanations, and communicate their knowledge claims. In such an approach, children's creativity can be used in the design of investigations. They could use understandings of patterns to help in this process in the way they juxtapose binaries of variables and layer or situate layer, sequence, or cluster observational or experimental designs. Their formulation of explanations can involve abductive and creative connections across contexts. Seeing how the tubular shapes in earthworms function in similar ways to tubes in other organisms and technological objects may allow them to develop creative insights into the structures and functions of the world within which they live. They also may develop creative representations through models, works of art, or poetry. Such thinking also models and promotes the very core nature of transfer of knowledge (Bloom, 2012a; Bloom & Volk, 2007, 2012). And, communicating can involve creativity as well. Rather than a formulaic "lab report," children may communicate their knowledge through drama, visual arts, music, film, and poetry. They also can examine how the knowledge they have created in one context is connected to other contexts. A science investigation may lead to understandings of one particular living system, but children can see how that living system is affected by society or social systems, by economic systems, by political systems, and so forth.

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KATHLEEN M. PIERCE

A SHAKESPEARE FESTIVAL MIDWIVES COMPLEXITY

FESTIVAL OVERVIEW

Shakespeare has no equal in our traditional English curriculum—or across the curriculum for that matter. With instant name recognition, academic cache, and themes inspiring universal and personal appeal, Shakespeare's texts invite compelling comparisons. Yet all too often, Shakespeare is passively admired rather than vigorously reckoned with in classrooms. Given his potency to ignite the imaginations of all kinds of students from vastly different backgrounds, Shakespeare can be reduced in the classroom to a curriculum cliché—something students are exposed to rather than a trigger for active exploration and invention. The Shakesperience festival aims to change all that.

The annual Shakesperience festival of learning and Shakespearean performance for secondary school students is based on two principles: Shakespeare is for everyone, and understanding Shakespeare requires actively playing with his words and ideas in the company of others. Called "Shakesperience" because of its emphasis on Shakespeare and active experience, the festival itself is held at my university and consists of interactive workshops in the morning and performances of Shakespeare in the afternoon. Groups of students and their teachers work for months to create original performances for festival presentation. University faculty have the festival's last word when they offer professional overall commendations to each group on their performance.

With metaphoric lenses borrowed from complexity theory, the activities surrounding a Shakespeare festival can be characterised as episodes of chaos, order, and emergent complexity. The participation of secondary students at an annual Shakespeare festival can be seen as engaged motion along the chaos-order continuum culminating in the creation of an original performance based on Shakespeare. The festival is not an acting showcase or drama competition but a "festival of learning and Shakespearean performance" with rules insisting that performances: derive from a Shakespeare play or plays, use Shakespeare's language intact, last no longer than 20 minutes, and rely minimally—if at all—on props, costumes, and electronics. The history of the festival and its design reveal that festival rules provide just enough stability off-site for diverse students and their teachers to create original performances. These rules also provide just enough stability for a festival day that is chaotic as well as organised, surprising as well as satisfying. From preparation off-site to the culminating festival day, human interconnections and feedback loops function

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 215–225.

to engage diverse adolescents with each other, with teachers, with Shakespeare, and with the theatre arts to allow deep dives into meaningful intellectual work and its exuberant celebration.

The most important notion in complexity theory is the concept of *emergence* describing the transition state that occurs at the edges of chaos where the system develops or emerges into higher levels of organisation (Ambrose, 2009; Davis & Sumara, 2006; Mason, 2008). Students in their groups move along the chaos-order continuum like other complex adaptive systems forming relationships among each other, with text, with new ideas, and performance elements. As a group progresses through festival preparation, efforts become increasingly complex and dependent on group internal diversity, diversity that must be assumed no matter how homogeneous a group might seem (Davis & Sumara, 2006, p. 138).

Complexity theory lends an especially useful lens for understanding the festival process from invitation through culminating performance. Various groups of students and teachers function like deeply engaged satellites prior to festival. Within each of these groups, festival preparation is episodically chaotic and orderly—moving along a chaos-order continuum. Complexity theory explains relationships among elements in dynamic systems that emerge as something new or of a higher order because the system was able to organise without being trapped at either end of the chaos-order continuum. Too much order or too much chaos inhibits the development of a complex system according to Ambrose (2009, p. 41).

Secondary students' preparation for performance at the annual Shakespeare festival can be seen as engaged motion along the chaos-order continuum with extreme chaos at one end and extreme order at the other. At the edges of chaos, productive complexity emerges as a balance between order and chaos. This productive complexity is the accomplishment of the festival process wherein each group gives birth to an original, 20-minute Shakespearean performance. It is instructive to regard performance preparation as part of an overall festival process that culminates at the festival, a process that also shuttles along the chaos-order continuum with bursts of productive complexity.

THE FESTIVAL AS A PROCESS

For its first few years, the festival design imitated a well-known secondary school Shakespeare festival that features dozens of school groups successively presenting student performances of Shakespeare throughout a week. Formal and informal feedback loops helped me realise that Shakesperience did not have to be imitative and that I might be missing important opportunities for learning and fun. For one thing, the diverse adolescents who converged on festival day did not get to know each other when one group performance followed another onto the stage. And I followed a tradition of awarded prizes for noteworthy performances when the festival was expressly "not a competition." Beginning to fathom all the complexity of social interaction and learning that occurred within each group leading up to the

Shakesperience, I understood that the festival format needed revision. Complexity theory helped me appreciate that there are many festival processes at work prior to festival day among each group preparing for Shakesperience. Shakesperience needed complexity—or rather, the festival needed to be redesigned to accommodate the emergence of complexity and all the thinking and energy conjured in the process of preparation.

In curriculum design, a *culminating activity* pulls all the new learning together in some kind of project or performance. Students assemble the parts of their learning to construct something new as evidence of their learning and accomplishment. So it is with Shakesperience preparation. However, when seen as a dynamic process that emerges from months of slipping and diving along the chaos-order continuum, a 20-minute Shakespearean performance is not very satisfying—especially performed before other adolescents who are virtual strangers.

The challenge was to devise meaningful but playful festival activities where participants could meet each other and spend some nervous energy before performances.

Informed by my experiences as a teacher/curriculum designer and the frequent feedback from participants indicating they wanted to "get to know the other kids at festival," I began festival reconstruction. With help from colleagues, the festival's morning workshops emerged. Now diverse participants converge as strangers at the university on festival day and move into smaller, deliberately randomised groups. Each of the groups set out together through a series of five 20-minute workshops where they get to know other students as well as learn, play, rehearse, and perform a new theatre arts skill. After morning workshops in the theatre arts, participants eat lunch and prepare as both audience and performers for the main event.

When the festival was excessively ordered and merely imitative of another model, my work as festival director lacked creativity and satisfaction. Observational cues and formal feedback loops helped me see the festival as process not a product. Complexity theory and the chaos-order continuum offer useful metaphoric perspectives with which to explain the dynamic social learning brewing within and bubbling up throughout festival processes. The festival's rules and design provide enabling constraints that instigate original expression and informed action in all phases of festival participation. Morrison (2008) explains how complexity thinking is useful for trying to understand and explain what happens among working groups off-site and why the festival day on campus must create deliberately the conditions for serious fun.

> Complexity theory stresses people's connections with others and with both cognitive and affective aspects of the individual person. …The natural consequence of this view of learning is an emphasis on the *conditions* to promote emergence, including motivation, enjoyment, passion, cooperative and collaborative activity (p. 22).

The festival workshops are extraordinary enabling constraints that achieve multiple goals. Rollicking rounds of interactive workshops like English country line dancing, Shakespeare's language, and combat choreography teach specific skills in speech, music, and movement and precede the afternoon performances. The workshops educate and entertain participants while everyone loosens up and makes new friends. In addition to learning new skills, participants develop empathy for each other during the workshops. Smart and focused, the workshops are extremely popular and create a fellowship and positive momentum for imminent roles as performers and appreciative audience.

The festival workshops help the university become a dynamic actor in Shakesperience too. First and foremost, the university's academic community provides wise and talented workshop instructors across various theatre arts as well as faculty who observe afternoon performances to offer astute, professional commentary. And the university's physical spaces open up amenably for workshop sessions. The art gallery, theatre main stage, dance rehearsal room, and lounges spaciously accommodate raucous workshop interactions and movement as well as create interesting contexts for secondary students from middle and high schools to experience.

INTERPRETING SHAKESPEARE AND CREATING A PERFORMANCE

Each group of students is under the guidance of a teacher attracted to the festival philosophy that encourages hands-on play or inquiry learning with Shakespeare to make sense and meaning of his work. Festival teachers work with their students for festival in varied contexts. Most of the festival teachers teach English or drama in the classroom, but the festival activity occurs necessarily outside of class. Participants include Shakespeare clubs or classes as well as groups who prepare a festival piece as a senior project together or because they are friends. Teachers play different roles with their student groups too; some are directors while others advise. Aside from managing all the tiny and huge details involved in getting 25 or so teenagers on a bus to festival, festival teachers help students immerse themselves in Shakespeare to experience and interpret his text in myriad ways. Inquiry learning is a way to solve problems, to interrogate a text or a situation and make connections to it and creating new learning. Little (2011) says that when literature is advanced and substantial, it encourages gifted students' "…deep thinking about the pieces…and creation of connections to other literature and to life" (p.167). The new English/language arts Common Core standards encourage use of high-quality source material to build knowledge through reading, writing, listening, and speaking. And drama is especially useful according to David Coleman, a lead writer of the English/language arts Common Core standards who says close analysis of specific scenes from drama provide a "particularly promising opportunity to explore at once textual evidence and visual interpretation" (Council of Chief State School Officers & National Governors Association, 2012; Robelen, 2012, p. 18).

Shakespeare's texts provide high-quality grist for the real work of festival—students' active contention with Shakespeare's words and ideas through, dramatic inquiry, and learning. Greene (1995) emphasised that mere exposure to art does not constitute an experience with art; she insists that the potency and experience of art require active engagement.

> The point is that simply being in the presence of art forms is not sufficient to occasion an aesthetic experience or to change a life. Aesthetic experiences require conscious participation in a work, a going out of energy, an ability to notice what is there to be noticed in the play, the poem, the quartet. Knowing 'about,' even in the most formal academic manner, is entirely different from constituting an [sic] fictive world imaginatively and entering it perceptually, affectively, and cognitively. (p. 125)

Whether or not the curriculum is Shakespeare, dramatic inquiry is pedagogically generative because it requires students to actively engage rather than passively observe. Gray and Sanders (2010) used educational drama to help their students learn and understand the historical, moral, and practical complexities of the Holocaust, and they report students move easily into the drama world where they synthesise nonfiction through improvisation to understand underlying issues. The synthesis involved in performance includes physicality—speech, movement, gestures, postures, and dance. Engaging various modalities helps performers to interpret and "feel" issues and content. In this way, dramatic interpretation provides important kinesthetic pathways for understanding. Physical movement helps performers better and more deeply understand meaning through the characters they enact. Performance also helps the audience to understand issues and ideas through characterisation and emphasis (Flynn, 2007; Landay & Wootton, 2012; Weber, 2005).

The driving Shakesperience concept is that in order to understand and make meaning from Shakespeare, we must engage actively with his words and ideas. This actively engaged meaning-making drives festival preparation within school sites and throughout festival day itself. Teachers and teaching artists (Bate & Brock, 2007; Edmiston & McKibben, 2011; Flynn, 2007) advocate dramatic inquiry as a way for making meaning from text and exploring aesthetic as well as socially relevant elements within a work. Such exploration can occur as a transaction between an individual reader and a text of course, but creating a dramatic rendering or interpretation with others widens and intensifies learning.

Dramatic Inquiry Assumes Collaboration

Shakespeare's plays are catalytic in terms of content that provokes thinking and group cohesion. The sociocultural nature of learning is assumed in festival processes, and festival preparation requires students and their teachers work with Shakespeare's plays and each other to create their own original festival performance. As Edmiston and McKibben (2011) say, "the complex human dilemmas that abound in the world of a Shakespeare play" help to focus a group's collaboration and in the process build ensemble (p. 88). Preparing a performance at festival represents an important milestone for each group, but the preparation requires group cultivation. For adolescents, there is something both playful and sophisticated in creating a performance based on Shakespeare. Working together in an inquiry, constructive learning mode encourages students to play with concepts in a deeper, more meaningful context. Such play also stimulates mental neural development (Ortlieb, 2010, p. 243).

The performance preparation is the foundation of the festival process, and each group finds its own way through inquiry and collaboration given the individuals in the group and unique school context. It is important that each group finds its own rhythms and purposes in evolving as learning community—not too focused or holding too tightly to their performance goal at first (Wenger, 1998; Wenger, McDermott, & Snyder, 2002). To function as a learning community, students need to get to know each other as they play together with Shakespeare's text, argue and decide on plays for performance, and create performance so that their intended interpretations of the piece are conveyed through elements like movement, words, actions, music, and props.

Working Along the Chaos-Order Continuum

The group process is inherently messy and chaotic, focused and confused. Complexity theory enables understanding and description of how student groups solve the *problem* or challenge posed by the following festival rules. The purpose is to interpret and explore Shakespeare's text through these guidelines:

- Each group prepares and performs one scene or scenes from any of Shakespeare's plays.
- Time on stage: 15-20 minutes
- Omit passages from text, but do not adapt text in any way, no modern language, no text mash-ups or reinventions.
- Play with context, and use brief modern English *bridges* if necessary.
- Limit costumes, props, and technical support. Music and/or sound effects must be performed live without electricity.

At first, the 20-minute rule chafes all participant teachers and students, but it helps students navigate the vastness of Shakespeare without dissolving into chaos on one end of their creative process or a mechanical line reading of Shakespeare text on the other end. Perhaps more than any other performance requirement, this 20-minute rule ensures students create a richly dense, meaningful festival presentation from the Shakespeare canon. Throughout the festival's history, violations of this rule have created the few wrinkles in festival organisation and good moods. The tacit agreement among all participants is that they play by the same rules. How performances bend the rules without breaking them is the result of creative complexity. Some groups returning to festival year after year enjoy the sublime challenge of working within the rules to explore Shakespearean themes in surprisingly novel ways.

If students collaborating to create a festival performance function as a complex adaptive system, then the idea of *enabling constraints* describes the imposed structural conditions like festival rules that help groups balance randomness and coherence while collectively processing their work (Davis and Suma, 2006, p. 147). This notion of enabling constraints provides a useful way to explain how certain festival elements provide the right doses of structure and freedom to an original 20-minute performance using Shakespeare's plays with unaltered text with limited enhancements. For instance, in a performance of *Julius Caesar*, all the performers donned white shirts and black pants with gold or maroon sashes; off stage, one performer pounded chillingly on his drum kit to emphasise a range of moods and complex emotions within the play.

ENABLING CONSTRAINTS OF THE FESTIVAL

The concept of *enabling constraints* borrowed from complexity thinking is useful for theorising about how the festival rules for performance and festival organisation modulate and encourage learning along the chaos-order continuum. Allowing for seriousness as well as silliness, the rules seem to enable rather than inhibit creativity. Some groups opt for performance of a single play, but many groups draw from more than one play to create thematic considerations like relationships with parents, the twisted course of love, and being unable to choose what's good for us—lessons that transcend time. Performance contexts vary too, from malt shops and television crime shows, primeval forests and psychotherapy sessions since Shakespeare's insights also transcend place. Gude (2010) says that in addition to giving students opportunities to engage in creative play, "…it is important to encourage students' capacities to make nuanced observations of inner experiences as they engage in creative work" (p. 36)

One of the most striking aspects of students' work along the chaos-order continuum is that they must reckon with each other in new ways. In order to interpret Shakespeare and create an original performance based on the interpretation, students dump and dive into modes and intelligences often dormant in the secondary classroom—interpersonal, intrapersonal, kinesthetic, musical-rhythmic, visual-spatial, linguistic, and logical. The festival time limit and electronic constraints force participants to integrate various arts into their performances to convey meaning. For instance, musicians played passages from Dvořák's *Ninth Symphony* during a fight scene and The Beatles' "When I'm Sixty-Four" as elderly characters waddled off stage to enhance mood and meaning that might not have been evident through characters' words and appearances.

Festival preparation requires students and their teachers to work with curriculum and each other in non-traditional ways—experiences that prepare students' festival performance and create deep bonds among participants. Students research their selected plays on film, on the web, with librarians and parents, with drama coaches and English teachers. One group, called "The Allusionists," create their performances as required on Shakespeare text but develop a script with layered allusions to more contemporary movies and texts. Another group performs the entire play from which they craft their Shakesperience performance for a community Shakespeare in the Park event. Edmiston and McKibben (2011) suggest "the complex human dilemmas that abound in the world of a Shakespeare play" help to focus a group's collaboration and in the process build ensemble (p. 88). This sense of group cohesion is evident in one student's description of how her group "collaborated and debated" about Shakespeare's words and their meaning: "…so it was really cool just hearing everyone's interpretation and really getting to know Shakespeare's language and finding a connection between our lives and Shakespeare's words."

During festival preparation, teachers play various but always crucial roles in preparing students for Shakesperience. Some are directors; others are club advisors, while still others are managers/advisors offering empty classrooms or off-campus spaces for rehearsals and steady consultations with student directors. For each group, teachers employ enabling constraints for their students to explore and create a festival performance that is a product but more significantly is meaningful to students. Erikson addresses the *just right* quality of pedagogical enabling constraints in his warning to avoid pedagogical extremes—excessive control on one hand and complete lack of direction on the other (Flum & Kaplan, 2012, p. 243). One teacher observes that the festival learning and preparation liberate her and her students from the classroom's excessive preoccupation with grading and testing.

> One of the greatest opportunities Shakesperience gave me was the chance to give kids the opportunities to be creative without any assessment or high stakes reward or penalty…to really experiment with what they were doing. And that doesn't often happen in the classroom because we have to generate grades; we have to measure everything….It really frees kids up, and that's just invaluable.

Festival preparation provides significant developmental opportunities for adolescents seeing themselves anew as agents capable of their own meaningful choices and contemplating the real-world dimensions of social and personal relationships. Bate and Brock (2007) explained the unique capacity of Shakespeare to help students examine point of view since Shakespeare teaches that for every position there is a counterposition and that we grow in intelligence and moral discrimination by continually going through the process of engaging with new problems and choices.

Students take deep intellectual dives as they make their own meaning out of the chaos of a Shakespeare play to create their own festival performances. One student says that the experience of working after school on their festival performance allowed the kind of opportunity that was a first in his school experience to:

> … really examine the language in depth and really see how each individual word is acting because we were trying to pick it apart to get a specific idea—to know what it meant, especially if we were going to be performing it we had to understand it.

Festival study and survey results suggest that the Shakesperience design, organisation, and personnel combine to create the conditions that foster emergence. A collection of group and one-on-one interviews with students and teachers combine with written surveys to create a rich narrative of participants' festival experience for analysis (Leavy, 2009; Paton, 2002). The word participants most often use in response to festival survey questions is "fun." Additionally, participants often express gratitude for the experience. In response to a question about "any surprises at the festival," participants report: how good the other groups' performances were, how nice other kids were, how great the workshops were, how cool the kids were in the workshops. A frequent response to the question about "any disappointment with festival," is a variation on "Yes, I'm a senior. So I can't come back next year." Participant teachers say that students return every year and comment: "Shakesperience was the best thing I did in high school." Analyses of survey and interview data suggest areas for festival tweaking and fine-tuning. Overall participant responses inspire and encourage my festival direction efforts. As festival director, I have learned that I cannot script complexity—but I can create conditions for its emergence.

THIS BE MADNESS, YET THERE IS METHOD IN'T

The chaos-order continuum offers a useful lens for understanding social learning and the dynamics along that continuum throughout the process of preparing a festival presentation based on Shakespeare. During the festival itself, each workshop creates its own chaos-order continuum of dynamic, applied learning among diverse adolescents.

Eisner (2002) suggests that while the standard view of rational planning maintains objectives as constants, the arts can teach the "importance of being flexibly purposive in the course of one's work" (p. 205). Through quick yet focused workshop sessions with the festival's teaching artists, participants experience fresh lessons on how to be flexibly purposive in collaboration and in performance. Connected through morning workshop activities, participants play to each other in performance and observe intently as audience. One teacher says:

> The one thing I really noticed was how they watched the other students perform. If they hadn't prepared a performance themselves, they would not have appreciated it. If they didn't get to meet other kids in workshops, they wouldn't have been as invested. But they completely got it!

While participants admire Shakespeare's depth and universal range, they are blown away by each other's diversity—within their own ranks and across the festival groups. Sometimes, participants write about themselves admitting that they "could never see myself understanding Shakespeare, let alone being on a stage." Teachers articulate the profundity of the experience and positive changes they witness among their student participants. Across the students' and teachers' interviews, the *unlikely kid* transformed by Shakesperience is a recurring theme and source of joy. The diverse studentswho starred on the girls basketball team, had difficulty reading, did not speak English in September, did not socialise, did not speak in class variously joined with their teachers and peers to create a festival performance.

I have witnessed unparalleled opportunities for inspired, authentic learning among a variety of students and their teachers during the festival processes. I have seen teachers weep with joy and affection for their students' courage and performances. Chief among lessons learned from hosting Shakesperience is the reminder of the lengths that wonderfully good teachers will go for their students—beyond prescribed curriculum, beyond the school day, beyond their personal budgets for pizza and snacks. One teacher said that she followed her students off the bus and was behind the group when they re-entered the school.

> You know how it is after a field trip… 'Ah, well, that's over,' and the kids scatter. But after Shakesperience, the boys went back into the school and were glowing. Administrators and other teachers told me that the kids walked around the building just beaming, so proud of what they accomplished at the festival.

Empathy and appreciation emanate within small groups and extend to new friends in fellow ensembles during festival. The process that begins with preparing a Shakespeare performance months earlier culminates splendidly on the university stage. When performances are finished for the day, university faculty and teaching artists working as commentators confer backstage and develop specific commendations based on observations and professional insight. Commentators offer an overall commendation to each group as well and commentary on "commendable characterisations" and "commendable choices." The commentators' incisive observations hold the theatre in rapt attention. Their commentary validates performances and hard work, teaches new lessons, and specifically recognises unique ensemble and collaborative efforts.

Shakespeare is the festival's marquee name, but he is not the star. The festival's brilliance owes everything to the teachers and students who take the festival's challenge to *bring it* to festival—*it* being their diversity, understanding, intelligence, courage, hard work, and collaboration. Performances result from learning and working along the chaos-order continuum and the productive complexity that emerges from the edges of chaos during preparation, an intellectual feat so stunning that participants dazzle themselves and each other. When the Mistress of the Revels officially closes the festival, each participant's happy confidence from productive accomplishment fills the theatre, and no one wants to leave.

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JACK TRAMMELL

THE ANTHROPOLOGY OF TWICE EXCEPTIONALITY: IS TODAY'S DISABILITY YESTERDAY'S (OR TOMORROW'S) EVOLUTIONARY ADVANTAGE? A CASE STUDY WITH ADD/ADHD

ABILITY AND DISABILITY

Some anthropologists and psychologists suggest that the ADD/ADHD arrangement of the prefrontal cortex may have been an evolutionary advantage 20,000 years ago when humans had a greater need to respond rapidly to stimuli in the environment and to consider creative or non-linear approaches to solving problems. In the present time, that same brain arrangement is often treated as a disability and the potential giftedness associated with it overlooked. In this chapter I briefly examine the historical etiology of ADD/ADHD and based on current neuroanatomical perspectives suggest that the degree to which the brain arrangement is considered medically disabling is problematic. I then consider cultural evidence from the last fifty years, which suggests that the popular concept of ADD/ADHD as a disability is rapidly being transformed. Finally, I propose that the concept of twice exceptionality itself (the co-morbid diagnosis of ADD/ADHD or other learning disabilities and giftedness, referred to as 2E) may actually be an obfuscation of a rapidly evolving human brain where today's disability may easily represent yesterday's, or tomorrow's, special ability.

THE EVOLUTION OF ATTENTION DEFICIT

The etiology of Attention Deficit Disorder (ADD) and Attention Deficit Hyperactive Disorder (ADHD) is a very recent phenomenon (R. A. Barkley, 2009, p. 1). Although clever pundits have diagnosed historical figures from Alexander the Great and Socrates to Lord Alfred Tennyson with ADD/ADHD, the formal study and diagnosis of the disorder is barely one hundred years old. Sir George Frederick Still, a British pediatric physician, began a series of lectures on children with attention and self-regulation difficulties at the Royal College of Physicians in 1902 and his descriptions mirror closely many diagnostic descriptors used presently in the *Diagnostic and Statistical Manual IV* (*DSM-IV-TR*, 2000, and still current as of this writing) definitions of the disorder (APA, 2000).

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 227–237.

Between Still's work in 1902 and the publication of the 1987 *DSM-III-R* with its formal christening of the moniker ADHD, various terms were used to describe the condition: minimal brain damage, hyperkinetic reaction of childhood, minimal brain disorder, mental restlessness, and disease of attention, for examples. In the present *DSM-IV-TR* there are three major subtypes of the disorder identified: predominately inattentive (I), hyperactive (II), and combined types (III). For the purposes of this chapter the term ADD/ADHD will imply all three major subtypes and the generalised symptoms associated with them, similar to the method used by the Centers for Disease Control and Prevention in aggregate data, and realising that the *DSM-V* will come out close to the time of publication (CDC, 2008).

According to recent CDC data, roughly 9% of American children aged 6 to 17 are reported as having ADD/ADHD, with boys being diagnosed at significantly higher rates than girls, and Hispanic children being diagnosed at lower rates than non-Hispanic black or white children (CDC, 2008; Pastor & Reuben, 2008). ADD/ADHD is generally linked to deficits in the pre-frontal cortex (PFC), an area of the brain associated with impulse control, decision-making, risk analysis, and what are referred to in general terms as Executive Functions (EF). Negative behaviours associated with EF deficits can include but are not limited to: distractibility, impulsivity, difficulty focusing, engaging in risky behaviour, short attention span, deficits in short term memory, impaired social skills, and chronic academic underachievement.

Typical medical treatments for ADD/ADHD include stimulant medications that generally increase dopamine and norepinephrine levels in the PFC. Researchers are not completely confident, however, of all the reasons why individuals with ADD/ADHD usually respond so well to stimulants, and research continues into the efficacy of various medications (Advokat, 2010, p. 1256; UWM, 2006). Alternate treatments include EEG biofeedback and specialised diets, neither enjoying the widespread popularity pharmacological interventions do. Therapy, counseling, and academic coaching are also commonly used in varying amounts both with pharmacological treatments and as stand-alone interventions.

If these facts were the only elements involved in the story, the solution might seem to be very simple: we need better, more thoroughly researched, and specifically targeted brain medications and therapies. Perhaps many reasonable people might agree with that position. Examined in a vacuum, the medical model of ADD/ADHD as an undesirable disorder of the brain seems to make logical sense. But that is not the complete story.

In addition to the primarily negative behaviours associated with the disorder, there are also more positive behaviours associated with individuals of the ADD/ADHD brain type. According to parents, teachers, and some researchers, doctors and anthropologists, children with ADD/ADHD also tend to: be free thinkers, move "outside the box," approach problems from a nonlinear perspective, show heightened abilities to engage in synthesised thought, and gravitate towards a general instability associated with creativity (A. Abraham, Windmann, Siefen, Daum, & Gunturkun, 2006; F. D. Abraham, 2007, p. 241; Armstrong, 2010; Glade, 2009). From a historical perspective, some even argue that the general traits of ADD/ADHD may have been an evolutionary advantage in a long-ago hunter/gatherer culture where those associated behaviours were more highly valued (Hartmann, 2003). The ability to respond rapidly to various and unpredicted stimuli in the environment would have been an essential skill in a day-to-day survival-oriented culture but would likely manifest in a more sedentary culture as an inappropriate and heightened desire for excitement and stimulation.

There has been repeated difficulty in agreeing on firm diagnostic criteria for ADD/ADHD. This is likely due to a variety of factors, including but not limited to: the difficulty of translating general behaviour characteristics into a reliable and valid measurement or test for a specific brain type; the overlap of traditional ADD/ADHD characteristics that have both positive and negative impacts on behaviour; shifting cultural norms about what constitutes normal behaviour (also impacted by an evolving developmental psychology); and the lack of a concrete medical technology that might facilitate a consistent and sensitive means of identifying a true disorder of the brain. In short, the evidence currently available suggests ADD/ADHD may be a true medical disorder; it may be associated with some or many more desirable brain/behavioural characteristics, or or it may in fact be a complicated combination of both.

Studies have reported conflicting links between ADD/ADHD and creativity or giftedness, in part because those constructs are largely driven by cultural norms, just as many of the "traits" associated with ADD/ADHD are. Nonetheless, the links are reported often enough that many researchers accept some level of correlation between the ADD/ADHD brain type and creativity or giftedness (A. Abraham et al., 2006; Healey & Rucklidge, 2006; Helding, 2012). A nascent theory of twice-exceptionality (2E) reconciles the apparent contradiction by suggesting that ADD/ADHD may be potentially both disability and special ability or giftedness (Crepeau-Hobson & Bianco, 2011; Eisner & Sornik, 2006; Healey & Rucklidge, 2006; McCullum et al., 2013; Trammell, 2005; Warshaw, 2006). It may in fact be one phenomenon with both positive and negative aspects to it.

The current state of knowledge about the PFC does not rule out a version of twice-excpetionality. While the ADD/ADHD brain is often characterised medically by deficits in executive functions housed in the PFC, it is this very same area of the brain that is also intimately connected to many elements of human behaviour that might be considered desirable, if not even actual forms of giftedness. For example, the evolution of language from simple sounds and a basic lexicon to a more complicated syntax and grammar is highly dependent on connections to the PFC (Aboitiz & Garcia, 1997, p. 381). If ADD/ADHD were primarily a disability or disadvantage, one might assume that there would be a higher rate of students with ADD/ADHD with language-related learning disabilities than in the general population. This is not the case according to the CDC and other data sources (CDC, 2008; Pastor & Reuben, 2008).

Moreover, there is lateral evidence to support a more generalised notion of twice exceptionality that identifies children who are both significantly disabled (not just with ADD/ADHD, but along the Autism spectrum or with learning disabilities) and gifted (Armstrong, 2010; Lovett & Lewandowski, 2006). While older mechanistic notions of the brain make the argument for a 2E paradigm difficult, socially constructed notions of the ADHD genius child are equally problematic. Between the extremes there is growing evidence that sometimes (more often than would be statistically predicted) disability and special ability come side by side in individuals. An informal study of honours students at a small college, for example, found that 49% of those enrolled in the Honours Program had a learning-related disability (including as defined ADD/ADHD) or a sibling so diagnosed (Trammell, 2005). Even proponents of a strongly medicalised ADD/ADHD often uncover relationships with higher intelligence or labeled giftedness in studies not intended to demonstrate such connections (Antshel, Hendricks, & Faraone, 2011). There is also strong cultural evidence documenting exceptional artists, writers, and leaders who are 2E at rates beyond what would be predicted based on CDC numbers, along with misperceptions about their psychological conditions, as well (Ghaemi, 2011; Wedding, Boyd, & Niemac, 2005). Studies even suggest that some students of higher intelligence use that ability to "circumvent" disability, thus likely biasing attempts to baseline the actual population numbers of 2E students (CEC, 2011; Ferri, Gregg & Heggoy, 1997).

Perhaps the most confounding of the ADD/ADHD and 2E variables is the growing appreciation for the brain as a non-static organ, evolving even through the adult years. Just as cultural norms for behaviour and paradigms like giftedness are socially constructed over time, intelligences in the brain are physically (evolutionarily) evolved or constructed over time. Current brain research suggests that concepts like creativity, complex language functions, and other advanced critical thinking tasks are increasingly understood as processes that cross hemispheres, connect and reconnect to many different localised areas of the brain, and involve short term memory skills that utilise many more areas beyond just the PFC (Aboitiz & Garcia, 1997; Abraham, 2007). Some studies on ADHD link significant differences in the parietal lobe to executive functions. To cite another current and specific example, keyboarding skills and Internet use from an early age in children of the 21st century appear to be resulting in measurably different adolescent brains, with a similar process even confirmed in adults (Fischbach, 2011; Helding, 2012).

Consistent with this chain of logic, the evolving nature of the brain and the implications of an embryonic 2E paradigm suggest that stimulant treatments and other ADD/ADHD interventions may actually dilute, dull, or redirect important brain functions that might otherwise be an advantage; they may also privilege medical solutions to problems more readily resolved through social and cultural mechanisms (Advokat, 2010, p. 1256). A growing number of practitioners even believe that prolonged use of stimulant medications may carry the risk of eroding cognitive ability and of actually mitigating giftedness (Hartmann, 2003; Hutchinson, 2009; Sparks & Duncan, 2008; Valkenburg, 2011). Criticism of stimulant medications has not abated, even as replication studies are completed and myriad new drugs come onto the market (Bratter, 2007; Hill & Castro, 2002).

All of these factors are intertwined in the profound difficulty that the current authors and editors of the *DSM-V* have encountered in bringing the newest edition to press (Adams, Milich, & Fillmore, 2010; APA, 2011; Weinberg, 2011). A fifth edition in roughly fifty years is ample proof that as medical knowledge is advancing there still remains a struggle to define exactly what ADD/ADHD and many other psychological disorders are in a larger medical and social context (R. Barkley, 2010; Davis, 1997; Wilson, 2010). Likewise, the definition of giftedness remains contentious (Carman, 2013; Renzulli, 2011). This is arguably in part due to behaviour overlap. When that is coupled with the fact that researchers still aren't completely sure why stimulants are as effective as they appear to be in many cases, a compelling case for adjusting the ability and disability dichotomy in the case of ADD/ADHD seems particularly relevant.

Such an adjustment should have at its core an understanding of the cultural position ADD/ADHD occupies, which requires both a historical eye toward greater medical sophistication and the anthropologist's evolutionary perspective. Or, to put it another way, we should not engage in "bad biology" by separating genes from their environmental context (Wilson, 2010).

HOW ADD/ADHD IS PORTRAYED IN AMERICAN POPULAR CULTURE

Easily identifiable cultural references to ADD/ADHD began to appear in literature, television, cinema, and in the news media concurrent with the medical struggles to define the disorder in the 1970s. Direct cultural references are relatively rare prior to that time, and never explicit. In popular culture, references to the overly fidgety child, or the overactive young boy, often seem to be consistent with ADD/ADHD. The outward behaviours associated with ADD/ADHD were generally linked to immaturity and lack of internal discipline, and were responded to with harsh external discipline. In the 21st Century, columnist and cultural commentator C. T. Goodson likened ADD/ADHD to "being a ten year old boy—think Bart Simpson" (2011). In Sir George Frederick Stills' time, the fictional character of Sherlock Holmes created by author Sir Arthur Conan Doyle exhibited some classic traits of ADD/ADHD twice exceptionality, including the well-known ADHD ability to hyper-focus on a single task to the exclusion of all other sensory inputs or distractions (another potential example of disability and ability), as well as a heightened risk for depression and addiction (also co-morbid with ADD/ADHD in many studies).

In the 1950s, the television character of Lucy Ricardo from *I Love Lucy* (1951-1957) readily comes to mind as an early media star of the ADD/ADHD brain type (Goodson, 2011). Lucy was impulsive, curious, quite easily distracted, but most of all her manic energy was an ideal visual description of the term "hyperactive." Later, the frenzied comedy of Robin Williams and then Jim Carrey (diagnosed in real life with ADD/ADHD) would become a modern reinterpretation of this frenetic, slapstick hyperactivity. Audiences loved Lucy but also experienced a kind of mental exhaustion after limited exposure to her adventures. One can imagine scenarios where an individual like Lucy could be labeled functionally disabled yet still have serendipitous strokes of genius; such an analogous student could prove challenging to teachers and parents.

Perhaps Lucy's television ADD counterpart without the hyperactivity might have been Barney Fife from *The Andy Griffith Show* (1960-1968), a character who literally could have had bubbles or text clouds following him around revealing his scattered inner thoughts. The character of Maria in *The Sound of Music* (1965) is portrayed as impulsive, unable to stop talking, as exhibiting rushed and disjointed thinking, daydreaming, etc. Zoe Kessler of Pysch Central calls Maria the ultimate "poster child for ADHD women" (2010). The message the character and the movie carry, however, is perhaps mixed. Maria's "medication" is a dominant male character who essentially imposes boundaries through fear and threat, though in the guise of romance. The same year (1965) Neil Simon's play *The Odd Couple* premiered, later spinning off a popular television show, a movie, and countless other related works. The play features Oscar Madison, who is sloppy and disorganised, impulsive, and scattered (but quite lovable). According to James Robert Parish in *It's Good to be the King*, the character is partially modeled after hyperactive comedian and writer Mel Brooks (Parish, 2007).

In the 1970s, special education was mandated by law, and students with ADD/ADHD presented a renewed quandary to educators. Such students did not always have classic learning disabilities but were often chronic underachievers. In the early interpretations of Individuals with Disabilities Education Act, 1975 (I.D.E.A.), students with ADD/ADHD did not always qualify for services and thus fell into the category of struggling students who did not have easy access to help. Later, they were labeled as "other health impaired" (OHI), again demonstrating the ambiguity the combination of their abilities and disabilities embodied.

By the 1980s, portrayals of ADD/ADHD in the mainstream media were more commonplace, less disease or medically oriented, and occurring side by side with the first major advertising campaigns for ADD/ADHD medications like Ritalin. The *Calvin and Hobbes* cartoon strip (1985-1995), for example, created by Bill Watterson, features a twice exceptional young man named Calvin in this time frame who lives in his own world of prehistoric dinosaurs and adventure and can only occasionally be disturbed enough to pay attention to school or other less important matters.

By the 1990s, movies with ADD/ADHD characters starring publicly admitted ADD/ADHD actors and actresses and with overt cinematic references to ADD/ADHD were becoming commonplace. In *The Mask* (1994) all three elements are present, with a manic Jim Carrey portraying Stanley Ipkiss, a normally mild-mannered bank clerk who suddenly finds himself an impulsive and wildly chaotic hero when he puts on an ancient mask. The television show *Seinfeld* (1990-1998) featured the whacky character of Kramer, who bursts into scenes unexpectedly, ignores most social conventions, and seems to have a brain that operates much faster than he can articulate his thoughts and ideas to others. Both actors have been referred to as having "comic genius," although they (or more accurately their characters) just as easily could be diagnosed as having most of the traits of ADD/ADHD.

In the 1997 film *Gattaca*, the primary character, Vincent, is tested at birth and given an eighty-nine percent chance of having ADD/ADHD. In true Hollywood fashion, and typical of the 1990s, the ADD/ADHD character becomes the hero, the person with the unique skill set to solve the biggest problems. Although the film has a darker side related to genetic engineering that stands alone as a cautionary tale, it also serves as a landmark film in the gradual normalisation of and even desirability of having ADD/ADHD, aided in part by medicine's inability to convincingly define ADD/ADHD. Many scholars of disability studies consider the movie *Gattaca* a ground-breaking movie in terms of exceptionality and the faults of the medical model of disability.

By the first decade of the 21st Century, film, novels, television shows and the Internet were confronting ADD/ADHD head-on with such works as *Music & Lyrics* (2007), *Julie and Julia* (2009), and even popular children's movies like *Finding Nemo* (2003) produced by Pixar, all of which overtly featured ADD/ADHD characters such as Dory, the distracted, forgetful, impulsive fish who initiated a now popular mantra to, "Just keep swimming" (Katz, 2011; Kessler, 2010).; Kessler, 2010). In the popular television show *Desperate Housewives*, Scavo took her son's Ritalin in order to cope with the many distractions and stresses she faced ("Really Desperate Housewives," 2006).

In general cultural terms, there is a great deal of evidence that ADD/ADHD has come of age in the early 21st Century (Schmitz, Fillippone, & Edelman, 2003). Through the media, and even through action research in the social sciences, individuals with ADD/ADHD have been struggling to "wrestle power back to themselves" (Danforth & Navarro, 2001). To have ADD/ADHD now is arguably as ordinary metaphorically speaking as a child's cow lick (unruly hair) which may be cute to one parent, yet involve the quick action of scissors from another.

If and when medical research and scientific understandings of ADD/ADHD evolve to more concrete definitions of a legitimate disorder (if they do), we may find that such information is irrelevant on certain functional and practical levels and that cultural shifts have left such imperatives far behind in the dust. Parents may, in the laconic fashion of characters in *Gattaca* who take genetic determinism for granted, actually engineer their children to have ADD/ADHD.

TOWARD AN ANTHROPOLOGY OF TWICE EXCEPTIONALITY

Even without arguing for a moment about specific definitions of what a disability, giftedness, or twice exceptionality really is or isn't, it is still apparent that survival skills and evolutionary advantages are not static; by definition, they change and evolve over time. The speed at which they change seems faster than ever before. The controversy over standardised testing for determining giftedness in school programs, for example, only highlights the degree to which the notion of giftedness is socially and culturally constructed based on skills and advantages perceived in time and place (Hartmann, 2003). “Giftedness,” as a label, may actually be a moving target.

In a similar fashion, disability is partially a medical construct based on physical difference (impairment) that can be relatively consistent across cultures, and partially a social construction based on specific cultural and behavioural norms that can fluctuate wildly between cultures (Barnes, Mercer, & Shakespeare, 1999; Brewis, Schmidt, & Meyer, 2001; Davis, 2002). A child with ADD/ADHD can be disabled in America, but venerated as an “old soul” in India. Even some physical differences are not static. One could cite, for example, certain deaf communities that don’t consider themselves physically disabled at all (Padden & Humphries, 2010, p. 393). In addition, the difficulties with publishing the *DSM-V* highlight the ongoing dangers of attempting to find static definitions.

Therefore, one must conclude that both the medical definition and the social context of disorders like ADD/ADHD are each rapidly evolving constructs, intertwined but still separated in important ways (Colley, 2010). Furthermore, what truly constitutes a disability (in the fullest sense of the term) can easily change across time and cultural context. If this is also true of constructs like giftedness, or creativity, then physical and cultural evolution of the brain place us in a conundrum, a dilemma so complex that one can argue that today’s disability may be tomorrow’s competitive advantage.

The social science evidence is growing in support of such a position. It is only recently, for example, that studies have begun to consider *understimulated* children, suggesting for the first time that it is society that is responsible for understanding children with ADD/ADHD and not the other way around (Cline & Schwartz, 1999). This is a concession that the medical/disorder model is at least partially flawed. There is also a growing assumption implicit in education and in popular culture that stimulation as a pedagogical lever is now primarily positive rather than an inherent disadvantage as it was perceived in studies of hyperactive children one hundred years ago when hyperactivity and disability were mired in a purely negative ontology. Studies also suggest that students in the present time are increasingly faking ADD/ADHD symptoms in order to obtain a diagnosis. According to Sollman, Ranseen, & Berry (2010), “significant motivations and incentives exist for young-adult students to seek a diagnosis” (p. 325). This is a complete turn-around from the 1970s when the advent of the label also brought along with it the tattoo, or the mark of disability stigma, with students who faked taking their medications rather than taking it from their friends as they do in the 21st Century.

Popular television shows, movies, characters in books, and re-framed advertisements for pharmaceutical companies all suggest that ADD/ADHD is being culturally repositioned as a more positive, normalised human trait, perhaps even a gifted and desirable trait. A recent liberal arts undergraduate was quoted as saying he “liked having ADHD, as it let him get to second level thinking.” In particular, the power of cinematic film to influence public perceptions about psychological conditions has been pervasive, largely becoming more positive (Wedding et al., 2005). To argue that the ADD/ADHD brain type was not possibly an advantage in some far-gone era is to ignore that it is arguably becoming an evolutionary and/or cultural advantage in front of our own eyes within less than fifty years.

In conclusion, the evolutionary and practical plasticity of the brain, in conjunction with rapidly changing cultural and behavioural norms, all suggest that today's disability may indeed represent yesterday's or tomorrow's advantage or giftedness. It may even simultaneously be today's ability. The notion of twice exceptionality itself may in fact be nothing more than a crude metaphor to explain a rapidly evolving brain that, situated in cultural contexts, is always changing and comprised of extremely diverse perceived strengths and weaknesses. If true, the notion of static, dichotomous labels—a persistent trait of modernism, science and medicine—may be experiencing the most serious attacks and questions it has faced to date.

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KATHLEEN M. PIERCE

MENTORING THE PUPAL: PROFESSIONAL INDUCTION ALONG THE CHAOS-ORDER CONTINUUM

PROFESSIONAL INDUCTION ALONG THE CHAOS-ORDER CONTINUUM

Mentoring has a long, varied history in the trades and professions, and the developmental or mentoring relationship is seen as critical in many fields and disciplines. Though it might be fair to assume that schools and universities take a developmental view of student learning within their institutions, senior faculty have been accused of *eating their young* when initiating new faculty who get the most challenging teaching assignments and undesirable duties. Even though formal and informal mentoring is offered in many academic settings, novice educators still struggle to interpret the demands of their new workplaces. Using the chaos-order continuum as a metaphoric gauge running along the zone of complexity within the context of academic workplaces, we see a chaotic swirl of new teaching assignments, students, and professional acclimation on one end and excessively-ordered orientation procedures and paperwork at the other end. In a manner so disorienting that their identities and purposes can seem to disintegrate, novices experience a pupal stage before emergence as a reassembled, integrated whole. The analogy invites a consideration of academic induction through the lens of complexity theory. Mentoring cannot eliminate novices' awkward and self-conscious experiences of induction, but mentoring might ameliorate the sting of initiation passages. Optimally, mentors help novices interpret and navigate the academic workplace and move toward complex, creative emergence in the new context.

YOU'RE ON YOUR OWN, KID

Mentoring the apprentice conjures images of an elder tradesman guiding the younger on the technical and finer points of plying a trade. And those images certainly still hold true in many trades, arts, and professions. The notion of mentoring the apprentice is hardly new, but the implementation of formal and informal mentoring systems to help educators acclimate to the complex demands of academic workplaces has become recently commonplace. Formal mentoring in academia responded to challenges faced by women and other minority groups who tried to survive and thrive in the academic work force. Mentoring is described as a developmentally

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 239–245.

oriented relationship between someone who is younger or less experienced and someone who is older or more experienced.

No one would deny that it is ultimately and undeniably the candidates' individual responsibility to land and keep the academic job. Sternberg (2013) advises new academics to seek out multiple mentors and "…seek out multiple sources of advice, sort the good from the bad, and take responsibility for your own career development." Such advice reveals a decidedly *sink or swim* pragmatism that reflects a range of senior faculty attitudes conveyed to novices in academic settings—indifference, caring, jealousy, challenge. Mentoring attempts to mediate the attitudes and comments of senior faculty and administrators so that novices might interpret signals dispassionately and distinguish imperatives from whimsies. An important assumption underlying mentoring is that it is a temporary developmental relationship to help novice educators emerge successfully from their career induction within the academic context.

This liminal phase of induction—between being the novice's being hired and established as successful educator in a given setting—is the most vulnerable phase of the novitiate. Liminality describes the *betwixt and between* aspect of novices' experiences at the start of their academic careers where they are invited into the setting but where full acceptance and tenure are withheld formally for a period of time. The novices' vulnerability within the new culture is complex and influenced by various elements within the various systems operating in the larger system of the academic setting—which is why complexity theory seems especially useful for descriptive analysis of the novices' liminality and mentors' potential for coaxing complex emergence.

Turner (1969/1995) describes the liminality of *threshold people*—typically the adolescents—who undergo ritualised social and cultural transitions. During such transitions, the initiates are depicted as invisible, *neither here nor there* as they move through this liminal phase. Turner further explains that liminal entities, such as neophytes in initiation rites, behave passively or humbly; they obey their instructors and accept arbitrary punishment without complaint (p. 95). Successful induction is not mere survival and compliance with institutional codes. Successful induction is realised when the novice emerges from a liminal or pupal stage having integrated a unique, creative personal and professional identity adaptable yet sturdy in the context.

Complexity theory metaphorically explains how academic settings operate as large systems containing mutually shaping subsystems. Trying to survive and adapting to their new systems, novice educators are enmeshed in an underlying tangle of liminal experiences where they have been accepted—but not totally—by the system where they begin their work. Complexity theory helps describe a way out for novices who can be seen as complex systems in and of themselves, and complexity theory suggests that chaotic and overly organised and rule-bound induction practices can optimally create conditions for novices' successful survival and creative emergence. Ambrose (2009) says that complexity theory explains relationships among elements in dynamic systems that emerge as something new or of a higher order. In this case, a novice is able to organise without being trapped at either end of the chaos-order continuum. Too much order or too much chaos inhibits the development of a complex system (p. 41). The most important notion in complexity theory is the concept of *emergence* describing the transition state that occurs at the edges of chaos where the system develops or emerges into higher levels of organisation (Ambrose, 2009; Davis & Sumara, 2006; Mason, 2008).

ACADEMIC SETTINGS AS WORKPLACES

The most costly budget item by far in the academic setting is faculty salaries, and universities need the creative workforce of teachers to accomplish their missions to educate students and produce knowledge. Hired for their scholarly expertise in particular disciplines, novice educators take up their academic work as both employees in a workplace and as educators in the complex system of students and curriculum in every classroom where they teach. Novices are reminded daily of their liminal status within the academic setting. Through good-natured teasing by colleagues, admonitions of administrators, and challenges from students, the induction phase is riddled with reminders of novices' temporary-until-proven-tenurable standing. Perturbing the complex systems and subsystems in which novice educators operate is the specter of promotion and tenure. Add the burden of interpreting successfully the instrumental and psychosocial aspects of achieving tenure to the novices' pupal stew of personal and professional identity formation in the academic workplace.

Unquestionably, novice educators are on their own to evolve into independent academic careers. However, appropriate mentoring during the liminality phase seems to offer novices both constraints and triggers to nudge them toward creative, complex emergence and away from entrapment at either end of the chaos-order continuum accompanying professional induction.

Just as the induction phase is ephemeral, so too is the window for mentoring novices in the academic workplace. According to Kram's study of workplace mentorship, mentoring relationships are constricted by time since the greatest opportunities for developmental learning occur earlier in the relationship (Eby et al., 2012). In beginning the complex work of teaching a variety of students in a variety of classes within a new school culture and work environment, novices work for professional survival yet cannot assess the context for themselves for appropriate mentorship. Realising this, many academic workplaces institute some type of formal and informal mentoring for new faculty.

MENTORING'S MANY FACES

The field of mentoring literature roughly corresponds to the developmental stages in the lifespan—youth, academic, and workplace. Nevertheless, while the areas of mentoring/lifespan scholarship have developed independently, they all describe mentoring in similar ways and "share the common belief that through sustained interactions marked by trust, empathy, and authentic concern, mentoring can have positive, significant, and enduring effects on protégés" according to Eby et al. (2012, p. 442).

The academic workplace straddles the mentoring literature because the context is academic, yet the mentoring specifically supports the educator as worker. Mentoring in academic settings tends to help protégés develop personally and professionally in their careers, and workplace mentors help orient novices to organisation and socialisation within the profession.

Given the novelty and liminality of new academic careers, novices are unable to impose order on their professional lives, they must integrate experiences and interpretations as well as learn adaptations within the new context. Theoretically, mentors can offer personal, professional, or combined personal/professional perspectives that can help novice educators interpret their early experiences in academic settings and determine informed action and adaptation. Depending on the institution and individuals involved, mentoring can look very different and serve various functions.

Researchers (Eby et al., 2013; Ghosh & Reio, 2013) indicate that there are characteristic features of mentoring in terms of likely support offered alone or in combination; these common characteristics include psychosocial support, instrumental support (specific to work-related goals), and/or relational support.

Owing to the independent nature of teaching and researching within specific disciplines and the need for novices to establish themselves as scholars within their new institutions, the option to accept a mentor is an important feature of mentoring the professoriate. When university mentoring programs exist, they generally do not consider their purposes to be epistemological per se. University mentoring programs urge the assignment of mentors within novices' home departments and presumably their disciplines to support candidates through the particulars of the promotion and tenure (P&T) process. By virtue of their missions and governance structures, universities enact various P&T rituals, procedures, and processes. Regardless of particulars, the P&T criteria spell out the conditions for ensuring life or death for faculty employment. Because successful P&T is paramount, mentoring can offer vital support to the novice.

Many academic settings offer formal and informal support for novices' acclimation. For instance, some campuses use their Teaching and Learning centres as faculty welcome centres and sites of ongoing informal mentoring around teaching and research on teaching. Given that few members of the professoriate are trained in pedagogy, mentoring around teaching can provide substantial help for faculty navigating complexity, chaos, and order within their own classrooms. Berberet (2008) reports that new faculty say graduate work did not prepare "them to teach, advise students, serve on committees, collaborate with colleagues, and think across disciplines," so hiring institutions use faculty mentoring, learning communities, and professional development planning to "maintain the currency of faculty expertise and enhance student learning outcomes" (p. 4).

Bell and Treleaven (2011) cite studies of mentoring in university settings that demonstrate positive outcomes for mentors and their mentees including collegiality, networking, professional development, and personal satisfaction. According to Bell and Treleaven, mentoring at universities has been informal traditionally, yet there are examples of formal mentoring for staff induction, improvement of teaching, assisting early career research, and "to actively facilitate academic women's development" (p. 547).

COMPETENCE AND PROMOTION AND TENURE

Even where formal mentoring programs are established and mentoring arrangements facilitated, mentoring is still offered to novices as a personal, professional choice and not a mandate. Granted, novice educators must make their own ways toward establishing themselves within academe, but theories of competence suggest that a sense of agency and competence can best be developed—might only be developed—in relation to others.

As novices try to adapt to their academic contexts and veer toward orderly compliance on one side and chaotic creativity or confusion at the other side of the chaos-order continuum, a sense of emerging competence in the new context seems a necessary adaptation. Complexity theory holds that there is a tipping point toward emergence of a self-organising system, but control of such emergence cannot be externally imposed.

However, a sense of agency might also be more socially or interpersonally driven than autonomous. Citing Markus and Kitayama, Plaut and Markus (2006) explain that even as the autonomous self tries to express itself through action,

> it requires a relationship or a social setting in order to 'be,' then the characterization of motivation will take new forms….Motivation will involve other people and social situations, and independent action or achievements will be less relevant or significant. Of greater importance will be behaving according to obligations, duties, rules and privileges. (p. 465)

Erikson saw identity formation as a lifelong process and maintained that identity formation occurs in relation to the interpersonal context and specifically in light of how people sense they are being judged by others (Flum and Kaplan, 2012, p. 241). Within the academic setting, induction rituals and protocols emphasise the external judgment of others culminating in P&T processes that are very public exhibitions of individual competence. Higgins and Kram (2001) indicate that satisfaction with one's work is positively associated with an individual's sense of success probability. They additionally theorize: Without high levels of career and psychosocial support from within one's own organization, individuals are likely to feel less confident that they are valued for their own abilities, thus decreasing their sense of potential (p. 281).

The tumult that novice educators experience in the academic setting seems analogous to shuttling along the chaos-order continuum with the chaotic realities of teaching, scholarship, and students at one end and the rules for P&T at the other. Mentors who engage with novices in shared work like collaborative investigations and writing demonstrate concrete ways to enact the role of mentor in support of junior faculty. Cowin, Cohen, Ciechanowski, & Orozco (2011/2012) explain how the intentional method of their co-writing helped break down the inherent power relationship between senior and junior faculty. The impetus for their study on mentoring relationships in academia was to address the "…stress, vulnerability, critical period in self-identity..." that characterises novices' liminal phases (p. 37). Cowin, Cohen, Ciechanowski, & Orozco describe themselves and their shared work and writing among junior and senior as that of novices and mentor deliberately trying to break down power structures inherent in the mentoring relationship. Such deliberate and deliberately self-conscious mentoring that addresses or even engages the novices in actual work encourages complex emergence. The potential for mentoring to combine psychosocial, relational, and instrumental support suggests that mentoring can create outlets for novices to escape entrapment in the chaos-order continuum.

MENTORING A CREATIVE PROFESSIONAL SELF

On the surface, induction and the road to promotion and tenure are prescribed for fledgling academics, but the rituals of induction unfold across dynamic and ritualised contexts of social interaction. Complexity theory helps us understand how awkward and fraught the novice can become entrapped between chaos and excessive order underlying academic workplace contexts.

For all the excitement and promises within the new academic context, novice academics must undergo a ritualised phase of acclimation and transformation. The view of academic induction afforded through complexity theory suggests how purposeful mentoring might help novices express their integrated complexity. Given the complexity of systems and individuals, effective mentoring cannot be prescribed nor its results predicted in advance. But timing and purposes seem crucial for effective mentoring of novice educators. Whether it is formal or informal, mentoring should allow novices to speak for themselves, to talk about their work, or even to collaborate in work.

Practically, mentors can help novices understand the many contexts in which they find themselves in the academic setting. Complexity theory helps us understand the pupal stew of novices' induction on the chaos-order continuum, yet complexity begs for emergence. Mentoring seems uniquely capable of influencing conditions of complex emergence. Over a cup of coffee, through co-teaching, or during discussion about dissertation findings, mentors build social relationships that help novices express themselves, explain their work, and begin to understand their identity in the new context. Most significantly, mentors can help self-organising, creative novices over the threshold of their academic careers. The casual even ephemeral nature of mentoring relationships can be nevertheless crucially instrumental for novice educators grappling toward integrative expression of identity emergent at the edge of induction chaos.

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SECTION 5

SOCIAL-EMOTIONAL DYNAMICS AS COMPLEX AND POTENTIALLY CREATIVE

MICHELLE E. JORDAN & REUBEN R. MCDANIEL, JR.

HELPING STUDENTS RESPOND CREATIVELY TO A COMPLEX WORLD

The content, structure and outcomes of educational experiences depend greatly on the internal models through which individuals and groups of individuals view the world. The structure and content of many school curricula and standards are based on intuitions, beliefs, and assumptions about systems and learning founded on the internal models of 18th Century scientists and philosophers such as Descartes, Newton, and Laplace. These scholars believed in *scientific determinism*; given accurate and complete information about the present we could have precise mathematical calculations of how everything in the universe worked and thereby be able to predict the future. In the words of Laplace (1902),

> Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it – an intelligence sufficiently vast to submit these data to analysis – it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes. (p. 4)

Scientific determinism also influenced the pursuit of efficiency and system perfection in the social professions—including educational systems—from the industrial age to the 20th Century (Rittel & Webber, 1973) and beyond. Based on these assumptions, a fundamental purpose of schooling often has been to prepare students for a life in which their challenge was to learn to participate in a finished and stable universe (Osberg & Biesta, 2003).

The purpose of this chapter is to suggest that a fundamental purpose of education is to help children prepare for life in a complex dynamic world. Educators' responsibility is to help children navigate a world that is fundamentally unknowable in many of its aspects and to relate to others in a world where interdependencies are key to creative structure and organisation. Students will live and work in complex adaptive systems for their entire lives. Thus, they need to see complex adaptive systems as an ordinary part of life where extraordinary things emerge. To this end, we discuss notions from the complexity sciences to guide educators in designing educational experiences.

In the 20th Century, the vision of complete predictability began to blur as new sciences developed. Einstein's General Theory of Relativity showed time and space to be inseparable and interdependent (space-time); Hawking's (1999) insights

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 249–268.

concerning black holes contributed evidence that information and matter can be permanently lost—irrecoverable. Tests of Heisenberg's Uncertainty Principle in quantum theory showed that position and speed of a particle cannot be simultaneously measured with accuracy; Prigogine and Stengers' (1997) dissipative systems theory showed that with enough external energy, systems could avoid the decay implied by standard thermodynamic theory. Studies of chaotic systems showed that even simple deterministic systems such as weather systems can have unpredictable trajectories. All in all, a picture has developed of a relational and probabilistic world, a world in which relationships generate order and pattern but not complete predictability or control. Thus, the dream of scientific determinism seems undeniably lost in scientific circles (Lighthill, 1986). Many educational stakeholders seem not to recognise or accept these conceptualisations of the world.

A particularly important branch of the new sciences relative to the topics in this book and this chapter is complex adaptive systems theory. While complex adaptive systems theory has been explored in depth in a variety of sources from multiple disciplines, the book *Complexity* by Waldrop (1992) provides a good starting point for the analysis in this chapter. Sometimes called "order-creation" science (McKelvey, 2004), complex adaptive systems theory highlights the importance of relationships and dynamic unfolding in the creation of system pattern, order, and novelty. It also highlights fundamental uncertainty in system dynamics. For individuals interested in creativity, complexity points to good news: fundamental connectedness, order for free (Kauffman, 1995), and surprise as a gift from an uncertain world (McDaniel, Jordan, & Fleeman, 2003).

The structural and behavioural characteristics of complex adaptive systems are not limited to a few, unique systems; complexity is not the exception, it is the norm. Perhaps of particular interest to the topics of this book, psychologists have used complex adaptive systems models to explain individual cognition (e.g., Goldstone & Janessen, 2005; Granic & Lamey, 2000) as well as group coordination in work teams, classrooms, and school systems (e.g., Arrow, McGrath, & Berdahl, 2000; Davis & Sumara, 2006; Guastello, Bock, Caldwell, & Bond, 2005; Lesh, 2006; O'Day, 2002). As San Miguel et al. (2012) described, the science of complex systems is trans-disciplinary and integrative, "a science of *systems of systems* across many domains" (p. 248). It calls attention to how systems are interdependent and mutually influencing. Complexity science also leads us to understand that many seemingly unrelated phenomena have common underlying complex dynamics and that common tools can be used to understand, influence, and deal with these dynamics. The study of complex adaptive systems is not simply a new research tool for scientists. Our stance is that the study of complex adaptive systems "stands as a new form of literacy for all, a new way of describing, viewing, and symbolizing phenomena in the world" (Wilensky & Stroup, 2000, p. 2).

Understanding common behaviours, processes, and functions of complex adaptive systems raises new questions for educators. How can students learn to act even when they are not certain of the relationship between inputs and outputs? Sometimes lots of effort leads to good results and sometimes it does not; sometimes investment of resources improves returns, and sometimes it does not; sometimes, after a long period of average performance, performance jumps to excellent without a complete understanding of why this is true. What issues are raised by complexity regarding trust, freedom, and responsibility in human social groups such as academic teams, families, and friendship cliques? If the world is endlessly creative, what are the implications for educating children to engage creatively with the world? In short, how can we foster children's abilities to thrive in a complex world?

We first discuss concepts from complex adaptive systems theory that seem relevant to these questions and tasks. We then suggest how educators can help students learn to navigate successfully as part of a relational, uncertain, creative world. We offer two overarching guidelines: help students live comfortably with fundamental uncertainty and help them learn to participate fully in dynamic relationships.

DEFINING A COMPLEX WORLD

Complex adaptive systems theory is a relatively new field, and complexity scientists do not completely agree on the defining characteristics or dynamics of these systems (Maguire, McKelvey, Mirabeau, & Orztas, 2006; Ricca, 2012). Nevertheless, five commonly discussed characteristics of complex adaptive systems theory can help us reflect on the educational goal of helping students develop creative approaches to living in these systems: non-linear interdependencies, dynamic unfolding, self-organisation, emergence, and co-evolution.

Non-linear Interdependencies

The identity of a complex adaptive system is encapsulated in the relationships among agents, connected in networks of relationships such that the behaviour of each individual agent depends on the behaviour of others (Mitchell, 2009). Interactions between agents in complex adaptive systems are frequently more complicated than additions and subtractions. Such systems are typically characterised by nonlinearity whereby the influence of two variables on a third variable is disadditive. This non-linearity can make systems highly sensitive to initial conditions whereby infinitesimal variation in starting points can lead to diverging system trajectories. Abrupt changes in system behaviour can result from small changes in sensitive parameters at critical thresholds. Positive feedback loops can destabilise a system, spreading and amplifying small signals leading to snowballing, cascading behaviours and abrupt qualitative changes in system states. Moreover, complicated causal relationships among critical variables can be multiple, reciprocal (rather than A simply affecting B, A affects B and simultaneously B affects A), and simultaneous (A affects B, affecting C). These circumstances lead to a fundamental unpredictability for the trajectory of a system and therefore to fundamental unknowability of future system states (Cilliers, 1998; Prigogine & Stengers, 1997).

As an example of the influence of nonlinear interdependencies on individuals in complex adaptive systems, consider, as did Ricca (2012), a child referred to counseling to alleviate classroom behaviour problems. Because how children "behave," is highly influenced by interactions in the complex social systems in which they live, such counseling may affect a child's behaviour outside the classroom but not inside the classroom. Seltzer-Kelly et al. (2011) recommended thinking about children's pathologies as an outcome of the interactions in a family system (or a classroom system) rather than as an individual characteristic of a child.

Dynamic Unfolding: Variation and Change

Scientists, educators, and policy makers alike often conceptualise variability as a problem to be solved, an outlier to be brought into line, an error to be avoided, or noise to be ignored (Jordan, McDaniel, Anderson, & Lanham, 2010). Variability is in fact a source of order-creation for many systems including heartbeats, brains, psychologies and languages, collectives of knowledge, social and cultural organisations. Biologists now widely understand, for instance, that variability often signifies wellness, and regularity can actually indicate illness or loss of health (Goldberger, 1997). Likewise, traditional scientific paradigms often assumed that systems seek optimal fit, moving toward equilibrium states. However, complex adaptive systems are continuously unfolding, always in transition, and change is a natural state for them (Orlikowsky, 1996; Wolfram, 2002). They do not seek and are generally not in a static equilibrium. As Waldrop (1992) explained, "new opportunities are always being created by the system" (p. 147). "You have a system exploring its way into an immense space of possibilities, with no realistic hope of ever finding the single 'best' place to be. All evolution can do is look for improvements, not perfection" (Waldrop, 1992, p. 167).

Complex adaptive systems evolve in unpredictable ways through local interactions with neighbours, and their trajectory is determined by slight variations and permutations (Bar-Yam, 2004). The term *history dependent* describes how a system's trajectory depends on all the events of its past but is not predictable from its past (Allen, Strathern, & Baldwin, 2005). System uniqueness comes about because "a complex system cannot be copied or fully understood without completely following the same history" (Ricca, 2012, p. 33). A striking example is the "malignant snowflakes" of cancer (Poste, 2013). Recent research sequencing the DNA of tumor cells in patients with pancreatic or brain cancer found that no two patients had the exact same set of mutations (Jones et al., 2008; Parsons et al., 2008).

From a complexity standpoint, individual identity can be seen as an ongoing dynamic process of participation in a situated activity that continuously develops from reciprocal interdependencies among personal (e.g., an individual's biology and personal dispositions), social (e.g., practical opportunities in daily life), and cultural (i.e., sociocultural norms and values) influences, or, as McCaslin (2009) described, the potential, the practicable, and the probable. Not only are all three of these influences constantly evolving, but their relative influence on identity shifts across an individual's lifespan depending on social events and conditions. McCaslin pointed to post 9/11 shifts in cultural beliefs, institutional roles, policies and voting patterns as one example.

Self-organisation

Individuals tend to impose centralised control where none exists (Resnick, 1994, 1996; Jacobson, 2001). For example, for hundreds of years people observed the foraging patterns of ants and assumed a leader must be directing the workers to find food sources. Only relatively recently has it been understood that foraging ants have no leader, their movements are coordinated through interactions with neighbours and the environment (Chowdhury, Katsuhiro, & Schadschneider, 2004). Rather than organisation being dictated by hierarchical control, order and structure in complex adaptive systems can arise spontaneously from local interactions among agents and between agents and their environment (Camazine, Deneubourg, Franks, Theraulaz, & Bonabeau, 2001). A key characteristic of these systems is their ability to reconfigure themselves, to continually self-modify in response to perturbations to enable adaptation and success in their environment (San Miguel et al., 2012). Patterns arise not through the imposition of top-down instructions, blueprints, or recipes but through decentralised, bottom-up processes of adaptation, learning, and evolution (Maguire et al., 2006).

The patterns of interaction among decentralised agents can be more or less stable or resilient depending on a system's structure. The evolution of those patterns is determined by slight variations and permutations dispersed through feedback and aggregation of local interactions. Positive feedback amplifies variation leading to novelty; negative feedback creates stability (Goldstone & Janssen, 2005). Diverse systems share the same underlying mechanisms for pattern-formation. The formation of ant trails, the spread of panic and viruses, the evolution of vocabularies and traffic patterns, and the construction of termite mounds all exhibit self-organisation (Bar-Yam, 2004; Camazine et al., 2001; Ke, Minett, Au, & Wang, 2002).

Jordan et al. (2007) argued that complex adaptive systems theory helps explain why classroom computer-mediated discussion groups develop different patterns of interacting and unpredictability in topical development even when they are situated in the same activity, discussing the same readings, and trying to learn the same cultural practices.

> Even very small random inputs can be iterated and amplified as students interact online, changing the patterns of discourse that unfold in a particular group… Although the fact that utterances are responsive and dialogically evocative constrains the potential paths along which conversation can unfold from a particular comment, many conversational paths are still available within this bounded space. (Jordan et al., 2007, p. 314)

Similarly, Kapur, Voiklis, and Kinzer (2008) described how participation inequalities evolve during online collaborative problem solving discussion and the effects of different scaffolding strategies on a group's ability to converge on a problem solution as members interact.

Emergence

Emergence is often described as a process by which a system of interacting agents acquires qualitatively new properties that cannot be understood as the simple sum or accumulation of their individual characteristics (Camazine et al., 2001, p. 31). New phenomena arise at higher levels from interactions of objects at lower levels (Wilensky & Resnick, 1999).

The human mind is an example often used to explain emergence. As Resnick (1994) mused, "How can a mind emerge from a collection of mindless parts when no one part is 'in charge' of the mind?" (p. 22). An individual's mental models can be thought of as emerging from interactions of experiences both instantaneously and over time. This idea can be carried up to explain group cognition; collections of people make group-level decisions that are different than the decisions of the individual cognitions that comprise the group. It is easy to assume that segregation by race, sex, or socioeconomic status is caused by strong preferences of individuals for like others. However, sharply segregated groups can emerge from the interactions of individuals even though no individual wants to live in such a segregated world (Schelling, 1971). Similar unintended consequences may arise from public policy decisions related to education.

Some researchers studying motivation in collaborative learning activities locate the origin of academic motivation at the level of individual group members. Others operationalise motivation at the level of group dynamics, assuming that social processes have a unidirectional influence on the individuals in the group. From a complexity standpoint, all group members are self-regulating individuals who influence group dynamics while simultaneously constituting a social entity that co-regulates engagement in collaborative activity" (Volet, Vauras, & Salonen, 2009). Social and individual processes exert concurrent bi-directional influence on how motivation emerges and is sustained during collaboration (Jarvela, Volet, & Jarvenoja, 2010).

Co-evolution

The concept of co-evolution describes the reciprocal interdependence between systems and their environment; not only are we adapting to the world, the world is also adapting to us. Commenting on individuals' propensity to think in unidirectional cause and effect relationships, Resnick (1994) wrote, "People often seem to think of the environment as something to be acted upon, not something to be interacted with" (p. 142). For instance, many traditional ideas of intelligence assume there is an optimal fit between an individual and the environment, and that intelligence is the correspondence to reality achieved by identifying the optimum fit (Schwandt, 2005). But complexity science leads us to understand that reality and perspective continually affect each other through co-evolution. What was an optimum fit ten minutes ago may no longer be optimal.

Complex adaptive systems do not exist in isolation; rather, there are complex adaptive systems of systems (Brown, Conrad, & Beyelar, 2012). Although many systems are clearly hierarchically nested (e.g., genes nested in cell nested in organ nested in body systems nested in individuals nested in families nested in communities, etc.), others are interpenetrating, enmeshed, and difficult to define (Cilliers, 2001; Ricca, 2012). Keim (2008) said, "The human body, for example, contains nine bacterial cells for every cell of our own. There's no clear line separating ourselves and our bacteria: We're walking ecosystems."

Of particular interest for our discussion of education and creativity is the co-evolution of individuals and the multiple social systems in which they live and are a part. Goldstone & Janessen (2005) wrote, "[O]rganized behaviour can be described at multiple levels, and …our thoughts both depend upon and determine the social structures that contain us as elements within those structures" (p. 22). Granic and Lamey (2000) explored the reciprocal relationship between the Internet, itself a complex adaptive system, and the cognition of the people who create and use it. These authors claimed that Internet participation may drive changes in contemporary modes of thought, beliefs, values, and cognitive styles, even as individuals continue to modify the Internet. Similar interdependencies are at work in student learning. Some theorists describe science education as a conceptual change process that occurs at the individual level. Others describe science education as taking place at the sociological (and/or cultural) level. From a complexity standpoint, what is needed is an understanding of how the psychological and the social co-evolve (Ricca, 2012).

The theme for the 2010 annual meeting of the American Educational Research Association was *Understanding Complex Ecologies in a Changing World*. Dr. Carol Lee expounded on that theme in her presidential address for that conference and in a subsequent article published in *Educational Researcher* (Lee, 2010). Drawing on ideas from human development, neuroscience, cognition, and cultural psychology, Lee suggested three ideas that orient educators and researchers towards this theme: "1) the intertwining of culture and biology in human development, 2) adaptation through multiple pathways, and 3) interdependence across levels of context" (p. 643). Lee emphatically resisted static assumptions of children's ability and homogeneity in children's developmental trajectories. She urged a shift from focusing on individual parts towards thinking about developmental systems as the rich ecologies of people's lives and a move away from deficit orientations to understanding the multiple pathways through which people adapt and develop.

EDUCATING CHILDREN FOR COMPLEXITY

Understandings from complexity science lead us to argue that a fundamental purpose of education is to help children participate in a complex world, a world where uncertainty and ambiguity are the norm, where stability is rare, and change is likely to be a common factor in a person's life. What knowledge, skills, practices, and attitudes do people need to deal effectively with nonlinear interactions, dynamic unfolding, self-organisation, emergence, and co-evolution? What experiences do learners need to have; in what practices do they need to engage? In the following discussion, we provide examples of educator and researcher efforts to address these questions. Table 1 also provides a description of the five aspects of complexity and their implications for education.

Table 1. Five Aspects of Complexity and Their Implications.

Because of…	**The thing of it is…**	**Therefore, students need to learn to…**
Nonlinear interdependencies	Present actions can have unexpected consequences.	Improvise, pay mindful attention, learn to learn instead of learn to know, hold impressions loosely, relate, converse.
Dynamic unfolding	Systems change over time and are history dependent.	Expect change and do not expect equilibrium, deal with systems as unique, satisfice.
Self-organisation	Order and structure are created through local interaction but may not be apparent at a local level.	Treat classroom conversation as collective improvisation.
Emergence	"We the expected" (Kauffman, 1995), the universe is a creative place.	Rearrange spatial and temporal relationships to allow the possibility of new elements and new systems; think across levels.
Co-evolution	Systems of systems make mutual adjustments, boundary issues.	Adapt to the world as the world is adapting to you.

That *nonlinear interdependencies* characterise complex adaptive systems means that children would benefit from understanding feedforward as well as feedback mechanisms, the potential impacts of small perturbations, and the influence of sensitivity to initial conditions. Helping children gain these understandings can be challenging because people tend to look for only one or two causes to explain patterns and structures they observe, but complexity teaches that patterns are often shaped by multiple nonlinear interdependencies among agents and between agents and their environment (Resnick, 1994). Educational researcher and innovators are creating tools to help. Curriculum materials developed by Forester and colleagues help children K-12 develop intuitions about system dynamics. By drawing causal loop diagrams of familiar system processes (e.g., the dynamics that lead to and from cleaning or not cleaning one's room; the dynamics of bullying), and social dynamics at play in works of literature, or physically embodying stocks and flows, children gain insights about interdependence, tipping points, reinforcing feedback, time delays, and exponential growth (e.g., Forrester, 2009; Hopkins, 1992). Free materials are available at http://www.watersfoundation.org and http://clexchange.org/ .

In physics classes, students could compare the trajectories of a single-pendulum and double-pendulums to understand that they can predict the periodic trajectory of a single pendulum, but they cannot predict the trajectory of a double pendulum due to nonlinear interdependences that lead to sensitivity to initial conditions. Similarly, elementary students could construct chaotic waterwheels and observe how the behaviour changes at critical points by controlling two simple control parameters (Strogatz, 1994). A chemistry class might experiment with chemical oscillators and follow up with computer simulations to create their own local catalysts that cause chemical reactions (Colella, Klopfer, & Resnick, 2001).

That *dynamic unfolding* characterises complex adaptive systems means that children would benefit from understanding system change and system stability. Students can develop understandings that rare events are more common than people tend to think by studying the behaviour of a stock market, or power law models that focus on the exceptional and treat the ordinary as subordinate (Taleb, 2007). Recognising that improbable opportunities and risks occur more often than one's mental models might predict changes one's relationship to them, discourse about them, and policies regarding them (Miller & Page, 2006). For instance, recognising the so-called Matthew effect on opportunities to develop sports skills (Gladwell, 2008) might help students see themselves and their teammates in more relational terms.

When asked to describe complex systems, young students tend to focus on what they can easily perceive, the static structural elements, failing to integrate processes and functions into their understanding of complex systems (Hmelo-Silver & Pfeffer, 2004). Thus, helping students understand the more implicit behavioural and functional aspects of complex systems may require calling explicit attention to structures, behaviours, and functions of systems such as aquatic ecosystems (Hmelo-Silver, Marathe, & Liu, 2007) or human respiratory systems (Hmelo et al., 2000).

Reading dynamic texts with children may help them see the world as dynamic and unfolding. The majority of textbooks and trade books most often used in classrooms are static texts in that they deal with known facts and finished histories. Contrast that with newspapers and other dynamic texts that privilege current events and unfolding stories. Through repeated exposure to dynamic texts, students can develop an understanding that they live in an ongoing, unfinished world (Jordan & Massad, in press).

That *self-organisation* typifies complex adaptive systems means that children need to learn how systems organisation comes about through local interactions among agents. To understand the unintended consequences that can result from local interactions among self organising agents, students could use checkerboards and two colors of disks to enact Schelling's (1971) cellular automata model of segregation in which agents follow a simple rule: If fewer than 30% of my neighbors belong to my class then I will move (see Table 1). From those decisions emerge sharply segregated groups after a short time even though no individual wants to live in such a segregated world, thus illustrating the mechanisms through which segregation can arise from even fairly modest preferences. Having students enact Schelling's model and modify it using their own simple rules can facilitate conversation about unintended consequences of individual interdependent actions on system-level characteristics, since varying the rules slightly can lead to different system dynamics.

Table 2. Schelling's Segregation Model

Setting the initial conditions	*Rules of interaction*
• Create a checkerboard of 64 squares in 8 rows and 8 columns. • Place 20 black disks and 20 red disks on the board, spread at random. • Each individual's neighbourhood is defined as the 8 squares surrounding it.	• If a disc has 1 neighbor, it must be the same color. • If a disk has 2 neighbors, one must be its color. • If a disk has 3, 4, or 5 neighbors, at least 2 must be its color. • If a disk has 6, 7, 8 neighbors, at least 3 must be its color. • Beginning wherever you wish, move in whatever order you wish. If a disk is not "happy," move it to any free space on the board that satisfies its requirements. • Only move one disk at a time. • Continue moving until all the disks on the board settle down or you are convinced there is no possibility they will settle down.

Likewise, agent-based computational modeling tools can help students gain intuitions about self-organisation by representing system dynamics through bottom-up computer simulations. Agent-based models consist of many adaptive agents diverse from one another on some characteristic(s) and interdependent with the set of agents in the model. Encoded with simple rules and running in parallel, each agent changes its characteristics and behaviour based on feedback from interaction with its local neighbours. The future state of each agent and of the system overall are dependent on rules of interaction. By applying the evolution rules of a model repeatedly, students can observe properties that emerge in a population of agents, and how system development occurs in a bottom-up direction. Students can use Netlogo (Wilensky, 1999) to explore non-constant changes such as the spread of fads through teenage populations, how cliques form on playgrounds, predator-prey relations in evolving ecosystems (Wilensky & Reisman, 2006), or the interaction of molecules that substantiate chemical reactions (Stieff & Wilensky, 2003).

Finally, facilitating students' reflection on their own day-to-day embodied experiences may help students gain insights about self-organisation. Levy and Wilensky (2008) asked sixth-grade students to pay attention as they spread out for calisthenics during gym class and then to explain those processes and the resulting pattern or organisation. Students who first focused on individual behaviours exhibited more sophisticated understandings of self-organisation than those who focused on aggregate behaviours. Physical Education teachers could intentionally allow students to experience self-organisation by leading them in a systems game in which each participant privately chooses two other participants and tries to keep equidistant between them as the entire group moves (Macy & Brown, 1998). Leading a reflective discussion that first focuses on what students noticed about individual behaviour and working up to examining aggregate level characteristics could be a useful sequence for helping students to understand self-organisation in complex adaptive systems (Levy &Wilensky, 2008).

That *emergence* characterises complex adaptive systems means that children need to develop the ability to think across individual and aggregate system levels. Students have robust misconceptions about emergent processes, frequently mistaking them for direct kinds of processes (Chi, Roscoe, Slotta, Roy, & Chase, 2012) and exhibiting slippage between individual and aggregate levels of a system (Wilensky & Resnick, 1999).

Biologists used to define the genome as the collection of genes that make up a living being. It is more accurate, however, to talk about the genome as a four-dimensional regulatory network defined in terms of spatial and temporal relationships among genes. Human beings share 95% of our genes with chimpanzees, but the relationships among genes are different in position and sequential order. The capacity of a gene to affect a system depends not only on its individual characteristics but also on the spatial and temporal relationship with other genes. For example, if the Ubx gene is removed from a beetle embryo at the right moment in time (temporal dislocation), the beetle will not develop its characteristic elytron (back wing)–even if the Ubx gene is re-inserted at a later time (Tomoyasu et al., 2005).

Another example of emergence in natural systems likely to interest young students is the dynamic patterns created through self-organising interactions in slime molds. When nutrients are readily available, slime molds exist as individual organisms. But when nutrients are scarce, they begin a collective restructuring of the population. First concentric rings form. These transform to rotating spirals. Then thin, dense streaks appear. The last pattern formed is of a multi-cellular organism resembling a mushroom (Chowdhury, Nishinary, & Schadschneider, 2004). Eventually, from the interaction of individual slime molds, a new entity emerges.

That *co-evolution* characterises complex systems means that children would benefit from considering system boundaries and recognise that there are multiple ways to draw them. Students need to understand that they live in and are part of systems of systems. They need to understand that the world is adjusting to them even as they are adjusting to the world.

To develop such understandings, middle school grade level teams could build a unit around a single model and explore that model from the perspectives of multiple disciplines. Math, science, and social studies departments might work together to create a model of the ecosystem in which their students live, exploring the relationships between different species, observing population trends generated by the ecosystem model, comparing those trends to the curves generated by algebraic models, and analysing the economic, social, and biological implications of various land management and population control strategies (Colella, Klopfer, & Resnick, 2001). Students in a system dynamics class might select a current event from the media and scenario plan possible futures. Throughout the year they could follow how the situation actually evolves, trying to track how systems of systems are unfolding. Modeling classes might explore how the logistic difference equation, network graphs, and cellular automata are all useful in understanding different aspects of phenomena as diverse as predator/prey relationships, the structure of terrorist organisations, and the spread of drug addiction.

TWO BIG OVERARCHING IDEAS

Taken as a whole, we see two key understandings from complex adaptive systems theory for understandings with which educators and other educational stakeholders might wish students to come away from their K-12 schooling experiences. We propose that students should learn to (1) live with fundamental uncertainty, and (2) participate fully in dynamic relationships.

Living Comfortably with Fundamental Uncertainty

Some aspects of the world are unknowable not because they are not meant for us to know and not because of a personal lack of experience or intellect, but because they exist only in the realm of the possible, potential, or probable. What will be is not yet. Children need to recognise that their inability to predict the future—like their parents' inability to predict the future—springs in part from the nature of the world. Because we live in a creative world that is still unfolding, we are likely to experience uncertainty frequently and to respond creatively to it. Students need to recognise the difference between uncertainty stemming from cognitive limitations and uncertainty stemming from complexity. They need to understand that different strategies may be needed to cope with different forms of uncertainty. Educators should help students understand that some uncertainties can be reduced through information gathering, but some uncertainties are irreducible and must be coped with by other means.

Human beings are not good at reasoning about uncertainty. We tend to overestimate what we know and can predict (Khaneman, Slovic, & Tversky, 1982; Langer, 1997). Our natural tendencies are to try to fold surprises into our current mental models. We often do not even recognise when something out of the ordinary has occurred (Weick, Sutcliffe, & Obstfeld, 1999). This behaviour is problematic for living in complex adaptive systems where uncertainty is fundamental and cannot be eliminated.

Educational experiences need to enable students to learn strategies for early detection of the unanticipated. If students can learn to recognise when something unexpected has happened, and in fact welcome it as a source of creativity, they may be less likely to look for blame when unpredictable events occur. Overestimating the amount of uncertainty in one's environment may be preferable to underestimating it because overestimating uncertainty leads individuals to pay more attention to the world as it unfolds (Perrow, 1999; Vaughn, 1996). Detection may be enhanced if students develop the ability to pay attention as things happen and learn as the world unfolds. It may be inhibited by assuming they know what is going on or by relying too heavily on past knowledge. Because the past is unlikely to repeat itself, information gathered about and from the past needs to be held lightly.

Individuals differ in how they tend to respond to and manage uncertainty. A study conducted with fifth graders collaborating to design engineering projects—arguably tasks that induce much uncertainty—found that some students openly shared their uncertainty with peers while others did not. Some students used a wide variety of strategies to manage uncertainty, including tactics to *ignore uncertainty*, such as by blaming or bluffing; *reduce uncertainty*, such as by asking clarifying questions or seeking confirmation for one's beliefs; *maintain uncertainty*, such as by expressing doubt or hedging; and even *increase uncertainty*, such as by purposefully opening the problem space. Other students, however, used only a small range of uncertainty management strategies (Jordan, 2012). Educational experiences should help students recognise and acknowledge uncertainty, increase the range of strategies they use to manage uncertainty, and evaluate when different strategies will be useful in different situations (Jordan, 2010).

Models are often considered tools for predicting the future. But even in the face of fundamental uncertainty, models are still useful for thinking about probabilities and the range of possibilities of future events. Educational experiences might be designed to help students learn to think of models as creators of expectation and explanation (McKelvey, 2004). Students should look not only for outcomes a model predicted, but also for unexpected outcomes. They should be willing to act tentatively and treat their action based on the model as an experiment in the real world rather than as a test of the model, recognising that there may be a difference between what they can predict from the models they build and what they can predict about the behaviour of a complex adaptive system. For example, some models of traffic flow assume that increasing control signals at an intersection will reduce accidents; however, there is evidence from other models that suggests increased use of traffic signals may cause increased accidents. This is because drivers become overly dependent on the traffic signals and thus less observant (Baker, 2004; Hilbring, 2005). Role-playing, pilot programs, and scenario planning can be seen as models for simulating possible, unpredictable futures in systems. New computational modeling and simulation tools such as cellular automata, neural networks, and multi-agent computer simulations may be particularly important because they make it possible to incorporate random and probabilistic events embedded in complex adaptive systems (Colella, Klopfer, & Resnick, 2001) and because they are essential for modeling order creation and measuring qualitative change that are hallmarks of complex adaptive systems (McKelvey, 2004).

Responding to fundamental uncertainty may require that students learn a different set of behaviours from following rules, procedures, and instructions. Fundamental uncertainty must be resolved through experimentation, creativity, and improvisation. In a probabilistic, surprising world, we are going to have to learn to wing it. Developing skills for improvisation and creativity allows one to create order by drawing together ideas or materials in unique ways. Improvisation and creativity allow students to keep going in the face of chaos, creating order through movement. Improvisation helps them recreate themselves when they feel that they have lost direction. As Davis, Sumara, and Luce-Kapler (2000) put it, “The very act of maintaining a coherent sense of self is an act of invention” (p. 195). Effective behaviour in the face of fundamental uncertainty requires that students pay close attention to the world around them, interacting with and reacting to others. Creativity and improvisation require not only creating new elements but also changing the spatial and temporal relationships among existing elements so that new things can emerge. Creativity is sometimes thought of as a process of creating something new. Sometimes it is. But more often, creativity is a process of re-combining much that is already there and allowing newness to emerge from this re-shaping. Good scientists and good artists are always working just beyond the edge of what they know. They feel their way, trust their instincts, make frequent leaps of faith—but faith based on all the tools at their disposal. They play around with ideas, imagine what-ifs, and take ideas to extremes either in their heads or on paper. They bounce those ideas off of other people they trust, either personally or professionally. That is the nature of their work and it is also the nature of a student’s work.

Participate Fully in Dynamic Relationships

If students live and learn in complex adaptive systems of systems, they need to develop an appreciation for and ability to practice participating fully in dynamic relationships. Current practices of schooling focus students’ attention on regulating individualistic pursuits. School experiences also need to help people learn to participate in dynamic relationships. Students are frequently taught about the importance of self-regulation for learning. They also need to become aware of the important roles that social regulation and help seeking play in learning and motivation.

Instead of attending only to their own understanding of a collaborative task, students also need to practice attending to their group members' understanding (Beth, Jordan, Schallert, & Lee, 2013; Jordan & Daniel, 2010). Classroom conversation may be a particularly rich avenue for self-organisation and emergence because it provides opportunities for transformational feedback as discursive participants adjust their actions to evolving circumstances (Erikson, 2004; Jordan et al., 2007). The potential for order, creativity, and identity to emerge from educational experiences can be supported by classroom discourse structures that are semi-open, predictable through repeated exposure, and where students are taught to engage in empathetic listening and to see themselves as contributing members to a collective performance (Jordan & Santori, in press).

Diversity in relationships is necessary for success in complex adaptive systems (McDaniel & Walls, 1998). Diversity's power lies in the fact that individuals distributed across a system have differing views of that system. They have differing representations of their environment and can jointly construct a representation of that environment that surpasses the capacity of any one of them (Weick, 2006). Collectives enable things individuals cannot do (e.g., Hong & Page, 2001; Surowiecki, 2004). Traditional statistical models account for the efficacy of collective decision-making by positing that errors about common variables cancel out of individuals' collected generated signals, and thereby increase collective predictions. Page (2011) argued, however, that the efficacy of collective decision-making for some types of problems derives from diversity of interpreted signals. Students may need help learning to capitalise on diversity because individuals are often reluctant to sacrifice individual face-saving for group accuracy (Hong & Page, 2009).

Relationships are dynamic in complex adaptive systems. As Miller and Page (2007) put it, "[W]e are at the mercy of a world characterized by change and connections" (p. 26). Students should therefore expect their relationships to change over time. Because human beings operate in dynamic relationships, we can never know with certainty how our actions will affect the world or how the actions of the world will affect us, only that we will evolve together (Bai, 2003, p. 27). Educational experiences can prepare them for evolving relationships with their parents, their teachers, their friends—even with their own memories, pasts, and selves. Rather than trying to decide once and for all who they are or "what they are going to be when they grow up," students need to learn to trust their ability to use their relationships to cope with the presenting world.

Order, creativity, and identity emerge from systems of relationships. Scholars have argued that creativity never belongs to a single person (Feldman, Csikszentmihalyi, & Gardner, 1994); rather, creative outcomes are the creative inheritance of a community (Seitz, 2003). As Virginia Woolf wrote in *A Room of One's Own* (1920), "For masterpieces are not single and solitary births; they are the outcome of many years of thinking in common, of thinking by the body of the people, so that the experience of the mass is behind the single voice" (chapter four, p. 65). More important in jazz groups than the quality of individual players is the quality of relationships between players who rely on respectful interaction to build trust under conditions of high variability. As Wynton Marsalis (1997) said:

> Jazz has to have the democratic feeling to it. One of the first is the spirit of improvisation. It has to have an attitude that is accepting of change… it is the sound of a group negotiating with itself,… an individual negotiating with a group, and also the sound of that group trying to find an equilibrium with itself and the attempt to find and maintain that equilibrium... You're not in control of what's going on, the whole group is in control of it.

Also emerging from systems of relationships is individual identity. What one is able to become and what one is able to accomplish is a function not only of his or her personal characteristics but also of the evolving systems in which he or she lives. The elementary school where the first author used to teach hosted a community service night in which they invited parents to receive information about and access to community outreach programs they might need such as health clinics and food banks, and also to participate in several school improvement projects such as campus beautification and equipment repair. Parents viewed themselves as both helping and in need of help. We are never only one thing and what we are is always changing.

The potential for student development is strengthened because we are working in complex adaptive systems rather than with a machine that has a fixed design. We can never know for certain what will be the results of our actions. In one of Bill Watterson's (1996) famous cartoons, Calvin said to Hobbs, "What if nothing means anything? What if nothing really matters? Or suppose *everything* matters?" (p. 77). Uncertainty and relationships lead to the possibility of making a big difference no matter how big the pond or how small the fish. You are unlikely to be able to ascertain when, where, and if you have been part of making a big splash, but uncertainty and relationships magnify each student's potential.

CONCLUSION

Educators need to help children relate to a world that is unknowable in many of its aspects, and they are called upon to do this in organisations that are themselves unknowable in many of their aspects. Drawing on insights from complex adaptive systems theory we argue that a fundamental purpose of education is to help children prepare for life in a complex world. Based on understandings from complex adaptive system theory, we argue that a fundamental purpose of education is to help children participate in a complex relational world, a world where uncertainty and ambiguity are the norm, where stability is rare, and change is likely to be a common factor in a person's life. Complex adaptive systems theory suggests the need for creative response to dynamic circumstances and that relationships are students' primary resources for creative response. Educators at all levels and in all disciplines can contribute to students' capacities to live effectively in a world of complexity. We stress the importance that they do so and urge them to familiarise themselves with complexity science concepts in order to begin today.

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KRYSTYNA C. LAYCRAFT

TOWARD THE PATTERN MODELS OF CREATIVITY: CHAOS, COMPLEXITY, CREATIVITY

This chapter provides a new approach to the study of creativity of adolescents and young adults by combining the idea of self-organisation with theories of emotions. To gather data for this qualitative research, hermeneutic phenomenology/ontology linked with narrative/biography methods were chosen. As a process of interpretation of the data, pattern models of the process of creativity are designed. There are some unique differences between the models of different participants' creativity, but in general they share common phases such as differentiation/chaos, integration/complexity, and dissipative structures/creativity (products of creativity in the forms of new movements, new writings, and new paintings). Creativity of young people is intertwined with strong emotions of interest, joy, and acceptance that enhance mental activity to global, open, and exploratory modes of attention and stimulate their thinking and enrich their imagination. These cognitive processes then deepen their emotions to complex emotions such as curiosity, enthusiasm, delight, passion, resourcefulness, and love that through a reciprocal reinforcement influences their selves. Creative people become more sensitive, more open, and receptive to the internal and external world. They develop into resourceful, imaginative, empathic, and spiritual human beings.

The synthesis here represents a new approach to the study of creativity of young people by combining the idea of self-organisation with theories of emotions. It is a part of the larger body of studies on development of creativity of adolescents and young adults. The main purpose of this study is to investigate creativity of young people and its role as a component of their psychological development (Laycraft, 2012).

The best-suited methodology to this research is a hermeneutic phenomenology/ontology linked with narrative/biography methods. To understand the process of creativity, I studied how young people interpret their lives and derive meaning from what they experience. As a process of interpretation of the research data, pattern models of the process of creativity were designed. These pattern models serve as conceptual tools to enhance our understanding of the researched phenomena of creativity (Laycraft, 2012).

In the first part of this chapter, creativity is discussed from different perspectives. Next the idea of self-organisation and the theories of emotions are introduced. In the second part of the chapter, the results of the research are presented by introducing,

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analysing, and interpreting the creative processes of three participants. Finally, comments on the importance of creativity of young people are presented.

DEFINITIONS OF CREATIVITY

There is a wide range of ideas about how to define the process of creativity. Creativity is a complex phenomenon, and understanding it requires studies from different perspectives. I present here definitions of creativity from four major perspectives: the subjective (intentional), inter-subjective (cultural), objective (behavioural), and inter-objective (social) (Wilber, 2008, 2010).

From the subjective or intentional perspective, creativity is defined as an emergence of a novel, relational product, growing out of the uniqueness of the individual (Rogers, 1954). It arises from above-average sensitivity and develops under conditions of emotional turmoil, mental tension, and external as well internal conflicts. Creativity helps to break the barriers of routine and liberate oneself from automatic experiences in order to achieve inner autonomy (Dabrowski et al., 1970; Dabrowski, 1973). For Merleau-Ponty (2004), an artist's creation emerges as a result of concentration or the coming-to-itself of the visible. An artwork is the actualisation of an artist's vision.

From inter-subjective or cultural perspective, creative expression is firmly grounded in culture and has its own profound impact on culture itself (Dilthey, 1976; Rudowicz, 2003). For Dilthey (2010), creative processes are the characteristics of human development during which the subject is able to evaluate his interests, perceptions, and ideas and to judge the value of various life options. Ingold and Hallam (2007) define creativity as a process that people undergo as they make their ways through the world. It is a power not so much as adjustment and response to the conditions of a word-in-formation as of liberation from the constraints of a world that is already made.

Vygotsky (1971, 1978) looked at creativity from the individual, social, and cultural points of view. He was interested in how creativity influences the individual's development over the lifespan, the role of creativity in cultural development, and how creativity expands both individual and cultural meaning. For Vygotsky, creativity transforms both creator through personal experience in the creative process as well as member of the social world via the creator's shared bits of knowledge and physical artifacts. In other words, creativity creates a lifelong zone of proximal development wherein people can continually learn from and contribute to their culture. Similarly, Csikszentmihalyi (1999) viewed creativity from the individual, social, and cultural perspectives by outlining a systems model of creativity. Creativity is a process that can be observed only at the intersection where individuals, domains (cultural system), and fields (social systems) interact. For Csikszentmihalyi, creativity could be recognised if it operates within a cultural system and is accepted and supported by communities.

From an objective or behavioural (neuroscience) perspective, creative processes are still unknown and puzzling. But lately some results on the neural mechanisms of creativity are starting to emerge. Dietrich & Kanso (2010) review neuroimaging studies designed to investigated creativity and insight and conclude that the literature on the neural basis of creativity is surprisingly fragmented and in many cases contradictory. Based on neuronscience, some conclusions about creativity are: creativity is not associated with the right brain; creativity is not exclusively associated with any single brain region, and creativity is a result of correlation among a multitude of processes and brain regions involved in it (Dietrich & Kanso, 2010). Focusing on connections between the frontal lobe (idea evaluation), the temporal lobe (idea generation) and the limbic system (emotions), Flaherty (2005) proposes a three-factor anatomical model of human idea generation and creative drive. There is a strong link between the limbic system and the temporal lobe that underlies the importance of emotions in creativity. Similar to Flaherty's model, latest neuroimaging studies (Ellamil et al., 2011) suggest that the medial temporal lobe is central to the generation of novel ideas. However creative evaluation extends beyond deliberate analytical processes supported by executive brain regions and includes more spontaneous affective evaluative processes supported by default and limbic regions.

THE IDEA OF SELF-ORGANISATION

Self-organisation is not a single theory or a conceptual model; it is rather an idea that explains the process of the spontaneous emergence of new patterns, changes, and novelties in a variety of systems whether physical, chemical, or biological. Recently, principles of self-organising dynamic systems have been introduced to psychology and neuroscience, especially in developmental psychology—the study of emotional development and of the relationship between cognition and emotion (Izard, 1984; Izard, Ackerman, Schoff & Fine, 2000; Lewis, 1995, 1997, 2000a, 2000b; Lewis & Granic, 1999; Lewis & Ferrari, 2001; Thelen, 1992; Thelen & Smith, 1994) and brain development (Lewis, 2005a, 2005b).

Self-organisation is nature's way of handling complexity in open systems that contain a large number of multiple, often heterogeneous, elements interacting nonlinearly with each other and their surrounding environment (Kelso & Engstrom, 2006, p. 112). Purely as a function of the inner dynamics of nonlinear interactions between the system's components, new states emerge spontaneously. The control parameter (e.g., temperature, pressure) creates the necessary conditions for far-from-equilibrium states and critical fluctuations. Near-equilibrium fluctuations are harmless, but far-from-equilibrium fluctuations play a central role (Prigogine, 1997). Fluctuations are continuously probing the system and providing opportunities for the emergence of new patterns (Kelso, 1995). When the system is in a far-from-equilibrium state, the rapid flow of energy links its components into more ordered patterns. The emerging patterns in turn influence the behaviour of the components of the system; this is called a circular causality (Haken, 1987). As a result of this process, all individual coordinating components of the system no longer behave independently but appear to be drawn into an orderly spatial-temporal pattern (Kelso & Engstrom, 2006). As a result of this process, the system generates something new: unexpected structures, patterns, and properties known as emergence (Bertuglia & Vaio, 2005). Emergence is a general principle that can be applied to understanding change and novelty in all natural systems (Lewis, 2000a).

Prigogine introduced the concept of dissipative structures (Priogine, 1980, 1997; Prigogine and Stengers, 1984). Such structures, to maintain their existence, must interact with their environment continually and maintain the flow of energy into and out of the system. Prigogine and Stengers (1984) wrote: "at equilibrium molecules behave as essentially independent entities; they ignore one another... However, non-equilibrium wakes them up and introduces a coherence quite foreign to equilibrium (p.180). This is the concept of "order through fluctuations."

Self-organising systems become more ordered and more complex over time. Complexity can be characterised by two dimensions: differentiation and integration. Differentiation refers to a variety of different components behaving in different ways. Integration defines the links among the components of the system and leads to order. Complexity arises when both of these aspects are present. It can be said that complexity is situated between order and disorder when the system finds itself at the *edge of chaos*. At this state, the system is displaying intelligent behaviour in adapting to environmental stimuli. A complex system is capable of change, adaptation, and growth (Bertuglia & Vaio, 2005).

THEORIES OF EMOTION

Emotions are dynamic and complex processes of change and play an important role in human development and individual responses to environmental challenges. Emotions are important factors in motivating perception, thought, and action (Frijda, 1986), and they give richness and meaning to individual life and relationship (Izard, 1977, 1984).

Thompson (2007) defined emotion as a prototype whole-organism event that mobilises and coordinates virtually every aspect of the organism. On a psychological level, emotion involves attention and evaluation or appraisal as well as affective feeling. Emotion manifests behaviourally in distinct facial expressions and action tendencies.

Emotion systems are highly sensitive to changes to the internal and external environment. They self-organise into coherent patterns of interacting emotional and cognitive systems, unique to the individual situation. These patterns/structures give the individual an enormous advantage when confronting complex and challenging situations. They are affective-cognitive structures (Izard, 1977, 1984; Izard, et al., 2000), emotional interpretations (Lewis, 1997, 2000 a, 2000 b), dynamisms

(Dabrowski, 1970, 1973, 1996), and complex emotions (Plutchik, 1962, 1980, 1994, 2003; TenHouten, 2009).

In brief, emotions are the core of being human and are closely intertwined with our thoughts, experiences, and behaviour. Emotions generate our energy and ability to make changes in the internal and external world. To design the pattern models of creativity, the psycho-evolutionary theory of emotions (Plutchik, 1962, 1980) and the affect-spectrum theory (TenHouten, 2009) are applied.

Plutchik (1980) treats emotions as adaptive reactions to the basic problems of life. He goes beyond Darwinian's idea by specifying these life problems and by introducing the concept that primary emotions must come in pairs of opposites: one for adapting to a positive situation or an opportunity, and one for negative, problematic situation or an obstacle. Plutchik proposes that there are exactly four problems in life: identity, temporality, hierarchy, and territoriality. Identity concerns membership in social groups and is a problem concerning two opposite primary emotions, acceptance (taking in) and rejection (expelling). Temporality leads to the development of social institutions such as the family, friendship, social communities, and others. Plutchik introduces happiness / joy and sadness as adaptive emotions to the positive and negative experiences of temporality. Hierarchy is a broad concept whose meaning includes power, influence, authority, and prestige. Anger and fear are the adaptive reactions to the positive and negative experiences of hierarchy. Territoriality is also a universal problem of life. Territory requires exploration and an ability to plan, monitor, expect, and anticipate. Opposed to the behaviour of opening territory through exploration is orientation, with its implied surprise and loss of control. The most generic subjective terms for these two emotions are anticipation and surprise (see Figure 1).

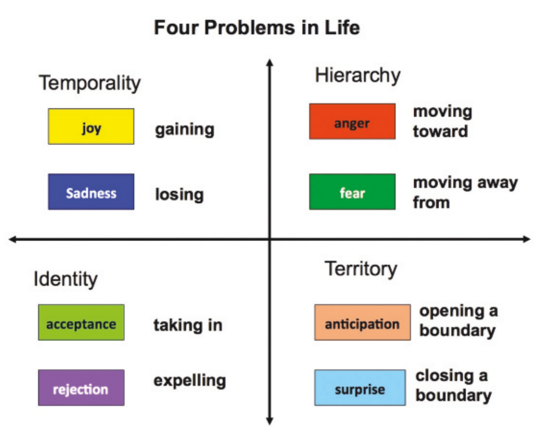

Figure 1. Plutchik's Model of the Primary Emotions.

Plutchik (2003) points out that the sequence of events in emotion is still an unsolved problem. It is not clear whether the feeling of emotion comes first or the correlated physiological changes. A major reason for this uncertainty is the fact that emotions are feedback processes. Stimulus events, either external or internal, act as the primary trigger of the emotion process. However, events need to be interpreted (cognition) in order for them to have an effect on the individual. Then, following the cognition or interpretation, a feeling state occurs as well as a physiological state of arousal. The arousal states are generally preparations for action. Feeling states also tend to be followed by impulses for action. When action occurs, the individual runs, cries, criticises, laughs, and so on. Such overt behaviour is not the end of the emotion process; such behaviour generally has an effect on the stimulus or condition that started the chain of events in the first place. Feedback loops, as is shown in Figure 2, may influence the impulses of action, the feeling state, the cognition, as well as the initiating stimulus. This process leads to the idea that feelings and behaviours can affect cognition, just as much as cognition can influence feelings (Plutchik, 2003, p.107).

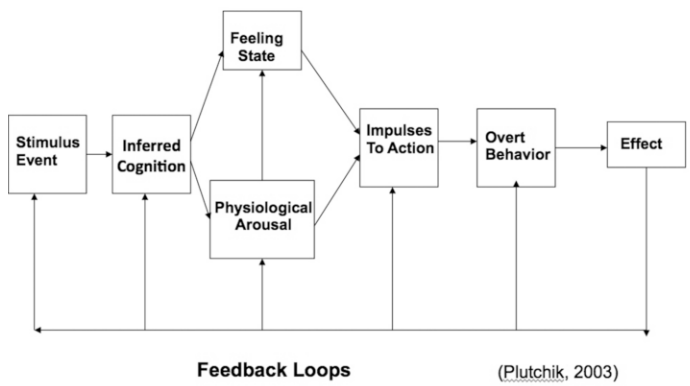

Figure 2. The complex chain of events defining an emotion.

In his theory, Plutchik (2003) also introduces the idea of a *derivate,* meaning that certain more complex structures are derived from other, more simple concepts. He proposes that beyond the eight primary emotions, all other emotions are derivative states occurring as a combination of the primary emotions. In some circumstances the primary emotion is activated and usually recruits other emotions. If two primary emotions are joined, the result is a secondary emotion; if three, a tertiary emotion and so on. Similar to color theory, the combining of these primary emotions at different intensities produces a variety of different emotions. They form emotional patterns that stabilise over repetitions and time and describe personality traits.

PATTERN MODELS OF CREATIVITY

The aim in participant selection for this research was to include participants who were actively involved in creative pursuits such as painting, circus arts, and writing. They were willing to talk about their experiences, and their contexts are diverse enough from one another to enhance the possibilities of rich and unique view on their creativity. I present here the pattern models of creativity of three participants: Krista Jennings, a contortionist, Marsha Park, a writer), and Eton, a visual artist. All names are pseudonyms.

KRISTA JENNINGS – THE CONTORTIONIST

Krista is an 18-year-old-girl and graduate of a charter school in Calgary. Her passion is the circus arts and contortion. She creates her performance pieces by herself. With great enthusiasm, Krista explains how she works on her performance pieces.

> It is usually some little spark of inspiration, whether it is a piece of music or some words, or very often something visual or something that I can hear. And from there, then I start to have ideas. It's usually in my head and I end up writing it down and doing a lot of research.

And eventually she gathers more and more ideas and concepts.

> I am reading a lot…especially poetry. Sometimes I take fragments that will be a starting point for the piece…I am keeping a notebook, writing my ideas, and drawing. Eventually they become bigger and bigger…And at the very end I take away because I don't need to get them to where I am now. Then I want to simplify it. Sometimes I am leaving ideas behinds. So I have to let go or to visit them later instead of trying to cram everything into one piece.

When Krista was preparing the piece for the audition at the National Circus School, the starting point was the painting of the seventeenth-century painter Johannes Vermeer, *Girl with a Pearl Earring*.

> Ever since I was little I was drawn to this painting. It stirs my imagination. It is so mysterious. At the same time I have a feeling that I can't describe when I see it.

Krista read the novel and watched the film of the same title.

> I enjoyed the novel and the film as well. And there was a piece of music I played over and over in my mind, so I decided to use it for my act. So I already had music picked up for my act, then I spent two or three months or so just let to sit and just allowing any ideas to come.

Krista started keeping a notebook and writing things down because she had trouble sleeping at night without this outlet. She desperately wanted to evoke some special emotions.

> Actually, I realized that I spent more time on the concept than I did on the movement. After about five months I realized that I had to start working on the movement because this is an act that I will be performing. I have to get out of my head and get into my body. And for a little while I have to turn off my brain and all the ideas and just allow my body to move. I just turn on music and just whatever comes to my body, just allow that to happen. But it is very challenging.

To put the concept, music, and movement together was very challenging process for Krista.

> On the night before performance, I was up late and could not sleep. There was one part that I had not planned out and in some way didn't feel right. At 1:00 a.m. at night, I was still working on this piece. And the idea for this one section came to me at 1:30 in the morning a day before the performance. It did come together. I had a lot of excitement and anxiousness that day.

Finally, after a long process of working on the piece, Krista was ready to perform.

> When I perform, it is really me, and it takes what I train very hard to do and brings so much creativity into it. I really connect with the audience and express myself doing something that I love doing.

After her audition, Krista felt a great relief, but she also felt excited and nervous.

> Of course it was again an excitement to show what I was working on and what I am passionate about but also very stressful. And I had it in my mind that it couldn't go any other way. It had to be perfect. It is such a rigorous school that any little mistake can be noticed. So I did actually…It went very, very well.

Model I

Differentiation Phase. The main emotions during the first phase of Krista's creativity are interest, joy, acceptance, and surprise. Interest, fascination, inspiration are emotions that open up a boundary of various experiences. Interest is evoked by the perception of novelties emerging outside of one's self or from within like imaging, memory, or thinking (Izard, 1977). James (1890) believed that only items that we notice (agree to attend to) shape our mind and without selective interest, experience is an utter chaos. Interest alone gives accent and emphasis, light and shade, background and foreground – intelligible perspective in a world.

Interest is feeling engaged, caught-up, fascinated, and curious. Krista is captivated by the painting *Girl with a Pearl Earring*. It holds her attention and maintains her focal awareness. She wants to investigate, become involved, and expand the self by incorporating new information.

Joy open individuals, moves them upward and outward, motivates them to approach challenges and to keep on working. People experiencing joy are more imaginative and creative (Kast, 1991). Krista is really enjoying working on her pieces by researching, reading a novel, and watching a film.

Acceptance, as an emotion, means acceptance of one's experiences as they are without any attempt to judge or to evaluate them, without comparison to past experiences or anticipation of the future (Rosenbaum, 2000) or being receptive to a joy-producing object (TenHouten, 2009). Krista accepts the process by becoming immersed in it and then allowing any ideas to come to her mind. In this phase, Krista becomes "open" and "receptive" to her external and internal environment. She becomes a participant and an observer of the ongoing processes of experience. These three emotions—interest, joy, and acceptance—create the state of openness and receptivity that allows her creativity to emerge.

Through the process of observing, researching, collecting ideas, exchanging information, and combining with emotions, Krista pushes her mind to a far-from-equilibrium state. This is a state of differentiation, a state of increasing entropy, a state of expectancy. In this state her mind as a complex system is extremely sensitive to small perturbations. The piece of music that she hears in the film becomes this small perturbation that changes her state of mind. She bifurcates from one state (attractor) to another by making a decision that influences on her creative process further.

The piece of music appears as a surprise for Krista. It begins with her sudden attention, that then changes into astonishment. She played this piece of music over and over again, so she decided to use it for her act.

Integration Phase. After the music was chosen, Krista spent almost five months allowing ideas to come to her mind. She started keeping a notebook and writing things down. Quite often at the end of this phase, Krista has too many ideas and has to eliminate some of them if they don't fit the concrete piece.

During this time, all mental elements are self-organising into new, unexpected patterns. Emotions evoked in the first phase (interest, joy, acceptance, and surprise), by linking with each other, create complex secondary emotions that are extremely essential to creativity.

Interest/anticipation by combining with acceptance creates resourcefulness that entails excitement in the face of mental challenges. Resourcefulness has a substantial cognitive element as it involves thoughtfulness in effort to overcome obstacles (TenHouten, 2009). Learned resourcefulness is defined mainly cognitive skill for the self-regulation of emotions, pain, and undesired thoughts. It includes the abilities to self-monitor internal events, use verbal abilities to label feelings, and use self-evaluative skills (Rosenbaum, 1983).

Krista becomes a resourceful person. She possesses an ability to open her own psyche for observation (anticipation) and through observation and analysis, she gains knowledge of herself (acceptance): "I have this strong drive and I try to learn how to cope with it in a more positive way…Frustration leads me to be persistent and to try again…I find that I have to be more patient to myself."

Acceptance joined with surprise creates curiosity reflecting a person's effort to maintain an optimal level of mental arousal and contributing to task-persistence (TenHouten, 2009). Curiosity is linked to exploratory behaviour and to the positive experience of conceptual territoriality, where information is incorporated (Berlyne, 1960). Krista as a curious person who seeks out new information, takes interest in it, and tries to learn as much as possible about it. She seeks an exposure to new concepts, ideas, and information.

Joy, together with interest, creates a secondary emotion such as enthusiasm, eagerness, or optimism. Joy combined with acceptance create love, passion, and finally, joy connected with surprise creates delight. Krista loves the circus art and is passionate about it (see Figure 3).

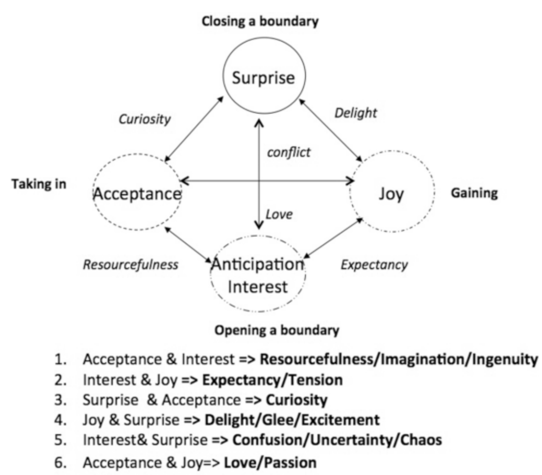

Figure 3. The pattern of emotions during Krista's process of creativity.

In this mental state of arousal and excitement, Krista feels animated and enlivened. It is this enlivenment that guarantees the association between cognitive, emotional and motor activity (Izard, 1977). Similarly, this state can be described by vitality dynamics (Stern, 2010) which refers mainly to the profile of the fluctuations in excitement, interest, and aliveness.

Siegel (1999) proposes that emotion serves as a set of integrating processes linking various systems in a dynamic flow across domains and through time. Within the brain itself, emotion links various systems together to form a state of mind. Dodge (1991) stated that all information processing is emotional in that emotion is the energy that drives, organises, amplifies, and attenuates cognitive activity and in turn is the experience and expression of this activity.

In short, emotional processing prepares the brain and the rest of the body for action (Siegel, 1999, p. 124). Damasio (2010) defines emotions as actions carried out by the body and accompanied by ideas and certain modes of thinking. Freeman (2000a, 2000b) proposes that emotions are essential to all intentional behaviours. Emotions are identified with the intention to act in the near future, and they are a “stretching forth “of intentionality. Emotions can also be measured by the magnitude of the tendencies to chaotic fluctuations in brain modules (Freeman, 2000a, 2000b). Freeman goes even further by saying:

> Emotionality is not weakness but a sign of strength, because of its depth, range, and complexity beyond the instinctual attitudes of other animals cannot develop without structuring by reason and language. The highest and most complex levels of emotion are seen in poets and other natural leaders who have the greatest range of personal insight, cultural vision, and predictive power. (2000b, p. 233)

Krista would not be able to evoke emotions like passion, curiosity, enthusiasm or delight if she were not deeply interested in, enjoying and captured by her subject, researching it thoroughly and sincerely.

Dissipative Structures

After spending almost five months finding the concept for her piece and evoking special emotions, Krista realises that it is time to start working on the movement by allowing her body to move freely. Her “mental movement,” her constantly changing flow of emotions, thoughts, images, and memories, her state of arousal prepare her to execute a physical movement (Stern, 2010). This physical movement of her act emerges spontaneously as a function of the inner dynamics of nonlinear interactions among Krista’s emotions, thoughts, images, and memories that create a new type of order, a new coherence, and some mechanism of “communication” among mental elements. But this type of communication can arise only in far-from-equilibrium. According to Prigogine & Stengers (1984), “The remarkable feature is that when we move away from equilibrium to far-from-equilibrium conditions, we move away from the repetitive and the universal to the specific and the unique” (p. 13). The far-from-equilibrium conditions relate to critical amounts of flow of energy and matter and provide an opportunity to discover new and unique patterns of behaviour. These new patterns of Krista’s movement could be understood as dissipative structures (Prigogine, 1980, 1997; Prigogine & Stengers, 1984) that depend critically on the far-from-equilibrium conditions. Krista’s movement of her act is sustained by the persistent dissipation of her energy (complex emotions) that flows through her body. In summary, the complex emotions combined with other mental elements are the driving force generating order and complexity in her act (Figure 4).

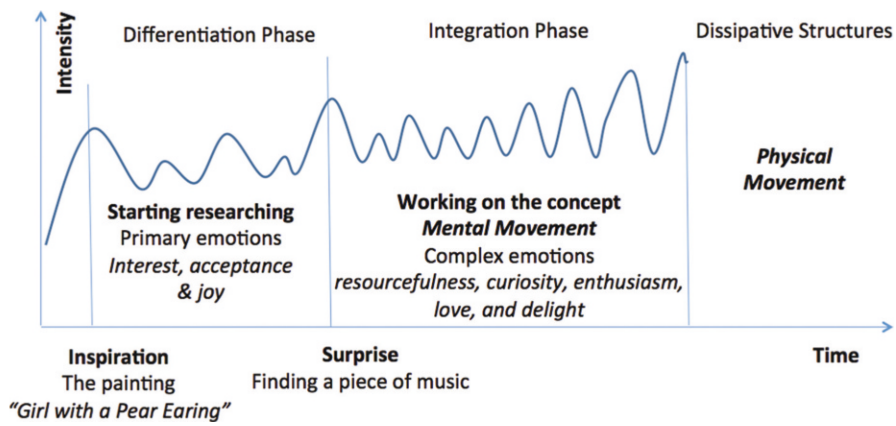

Figure 4. Krista's process of creativity.

MARSHA PARK – THE YOUNG WRITER

Marsha is a 19-year-old writer/journalist who has just finished the two-year Journalism Art program at Sothern Alberta of Institute of Technology. She is fascinated with the spiritual problem of the mind-body connection and is trying to figure out a solution to it. For her, art is the only way to use both mind and body at once.

> It happens in my writing and in my art too. Sometimes, I feel like I am connected to some form of energy, like this "Chi" energy. I just feel like a stream going through everything, like invisible but you know that it's there. You just feel it. It just vibrates.

Recently, Marsha discovered a new way of expressing herself through writing as she explains.

> I'm journaling another night. I'm just starting to write with an ink pen… When you write, you contemplate more when you do it by hand because your speed is not there. I'm just starting with a purple pen and I'm drinking a purple tea out of a purple cup. My mom gave me my grandmother's cup that she brought from England. I'm just writing with purple pen. Purple represents creativity and spirituality. During that day, it was almost like a bolt of lightning right here and then I felt it in my eyes and that hurt me so badly. I took Advil and lay down. When I woke up I felt so sensitive, so insanely sensitive to just everything around me. I felt like a vibration. I was so alive that it was almost scary. When I was writing this I started realizing that the pain that I had felt was like a general body pain that happened to all women throughout history and that was connected to Mother Earth. I started relating that the pain that

I am going through is like the pain Mother Earth is going through—all the transitions, earthquakes, these natural disasters.

Model II

Differentiation Phase. Before starting her writing, Marsha assembles the purple ink pen and the purple cup that her great-grandmother brought from England that has now been passed down to Marsha. This cup is a family treasure and has a special meaning for Marsha. She also prepares some special purple tea that calms her mind and amplifies her inner voice.

While collecting these items, Marsha has had time to gather in her mind images and thoughts about the women in her life, her feelings of love and acceptance toward her mother who has suffered so much throughout in her life, and her spiritual knowledge about the meaning of colors. She experiences enormous tension, discomfort, and pain. This mental state can be described by background emotions introduced by Damasio (2003). Background emotions are intimately linked to consciousness, moods, drives and motivations. They are induced internally rather than externally. Background emotions are not discrete affective events but are rather a continuous emotional experience. Marsha's strong, unpleasant emotional experience acts as positive feedback and pushes her mental state for change by making a decision to take a nap.

Integration Phase. From a complexity science perspective, Marsha's nap is a period when her thoughts, images, memories, and feelings combine and organise into completely new, unexpected, and complex patterns or configurations that are waiting to emerge from her unconscious. Marsha's unconscious process is primed by her intentionality, her desire to write, but because of her pain it is necessary for her to divert from this task by taking a nap. It is believed that although the mind is activated by sensory inputs, the unconscious mind is understood as an internal environment where meaning may be constructed entirely from within (Freud, 1915/2001; Modell, 2003). Modell (2003) argued that unconscious autobiographical memory, the memory of the self and its intentions are constantly recontextualised, and the link between conscious experience and unconscious memory is provided by metaphor. Metaphor is a mode of cognition that can transform meaning between dissimilar domains, like the domains of past and present time, and generate new perceptions. Imagination is the result of this recombinatory metaphoric process. Imagination is unquestionably an aspect of intentionality. Perception, memory, and imagination are all interwoven into the fabric of intentionality and will determine the nature of our actions in the world (Freeman, 2000a). Freud (1915/2001) viewed the unconscious as a potential source for meaning and that could be taken as an expression of intentionality. Meaning is achieved through action in the world, and in turn, the self is altered by that action (Modell, 2003).

From a neuroscience perspective, Marsha's nap is the default mode of the human brain as proposed by Raichle et al. (2001), who discovered high levels of activity in certain parts of the brain during passive "rest" periods when individuals were not focused on the external environment. Buckner et al. (2008) proposed that the brain's default network can be understood as multiple interacting subsystems. The medial temporal lobe (MTL) subsystem provides information from prior experiences in the form of memories and associations that are the buiding blocks of mental simulation in the form of novel ideas. The medial prefrontal subsystem facilitates the flexible use of information during the construction of self-relevant mental simulations. These two subsystems converge on important nodes of the integration including the posterior cingulate cortex. Schilbach et al. (2008) stress that the mode of default network functioning can help to integrate self-referential information, facilitate perception and cognition, and provide a social context or narrative in which events become personally meaningful.

Dissipative Structures

When Marsha wakes up, she feels extremely sensitive and alive. Activated complex emotions combine with thoughts and images that act as a flow of energy going through her becoming a driving force for her creativity. Marsha dissipates this cumulative energy through her writing. Her writing can be compared to the "dissipative structures" whose existence depends on the flow of energy (Prigogine, 1980; 1997). This is Marsha's moment of "awe," her eye-opening experience. She knows that this experience has opened her up to something powerful. She lets it happen and is surrounded by this creative process. "It is my new process," she shares (see Figure 5).

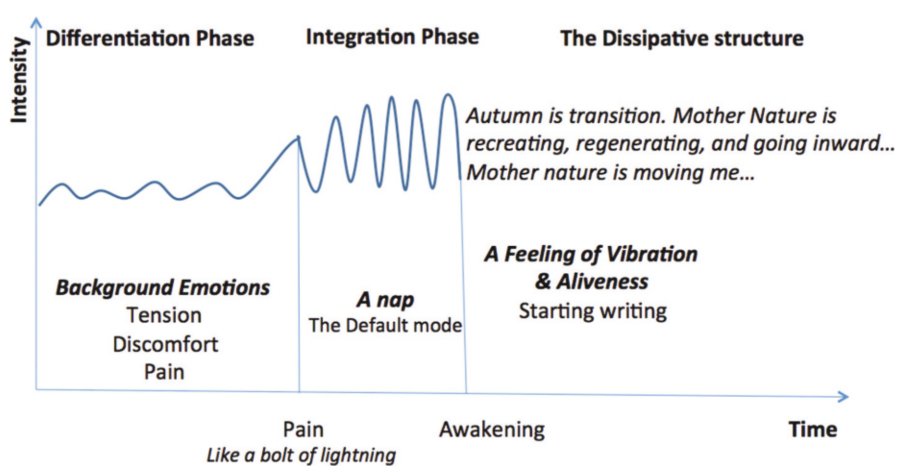

Figure 5. Marsha's process of creativity.

ETON - THE SPIRITUAL ARTIST

Eton is a fourth year student of visual arts at the University of Calgary. He is deeply interested in spirituality. By reading books on Zen and Buddhism, he is getting a new perspective on his life and says, "I kind of created my own religion, a personal religion, based on what I thought was good, what I thought was virtuous." Eton becomes more friendly and sensitive to other people and regrets his selfish attitude during his college time and admits, "Reading these books, it gives me a new perspective on my life, not just using everyone as a ladder step." In the interview, Eton explains his artistic practice.

> In the first and second year, there was a focus on the technical drawing. I was really good in drawing models. That was my thing. That was what I loved to do. When I came here [University of Calgary], I was like that I am just going to throw it all out of the window. I am going into non-objective abstract. I am going to take lithography because I have never done it. I started getting interested in non-objective art as a way of expressing something deeper, something spiritual, something mystical, something that is not in this world, transcendental philosophy. I become really process-oriented. I want to really focus on the process. It is a sort of moving meditation, doing repetitive movements, trying to draw circles over and over again or using circular symbols.

Eton is doing lithographic prints by grinding the stone for hours to get unexpected images.

> It becomes meditation. The result is uncertain because there are so many steps before you get the actually image. This is like Zen practice of letting go, not clinging and not grasping, but the process of what will be.

Eton spends a lot of time doing these lithography prints. Some of his prints take him days to complete, whereas others are quick expression that might take him two minutes to do.

> It is energy, in that time, in that movement. This is like Japanese Sumi brush feature. Everything is about this moment, recording this moment, recording this motion.

Before starting this process, Eton has to quiet his mind with breathing exercise and says the breathing exercise: "… kind of overcomes my mind, quiets my mind so that I can reach something deeper." When I ask him how he understands this "something deeper," he answers:

> I think that it is something bigger than me. It is coming from me and through my hands...It is like an emotion but not like anger. It is something much more complex. You lose track of time. It is like ego disappears if you are doing

> right. You are forgetting who you are, and what you having for lunch. It is like meditation making art. I am trying to make a huge connection between them.

In the third year, Eton did not want to paint realistically, only abstractly.

> But now I come to realize that all art is the process. Now, I am coming back to figuration. You can embody that emotion into a piece of art whether it is abstract or realistic. It is more in what state you are when you are making it and if you are connected. If you are not connected, it does not matter what you are doing, it shows up that you are not there.

Because he wants to challenge himself in the fourth year of his study, Eton plans to make a copy of Vermeer's paintings and explains:

> It is also another impulse inside of me…Everyone dismissed me as 'This is an abstract guy who can't draw or paint realistically.' It is a bit of a surprise. 'This is Vermeer. Who painted Vermeer?' This is a part of that. I challenge myself. I challenge my colleagues and my professors too. I might surprise myself or I might not be able to do it… It is an interesting process, dealing with the unknown.

When I asked what it means for him to be an artist, Eton says that he has been thinking about this for a long time. He sees it as a spiritual practice and states with passion in his voice:

> If I don't enjoy the process and it leads me into the ego direction, I don't want to do it. I only want to be closer to my being, to my soul. My girlfriend and I, we want to do only what we call good for goodness sake, what is right to do. Through my painting and her writing, we want to develop these virtues: patience and understanding, forbearance and being in the present moment and being the wind of change in this world. If a hundred people change, it is good. If ten change, it is good. If one person changes, it is just good.

Model III

Differentiation Phase – Primary Emotions. Eton is deeply interested in non-objective art as a way of expressing something deeper and something mystical. He experiences enormous joy during this process. Eton is completely immersed in and connected to the process of creation. Because of many steps involved in the process, the result is always a surprise for Eton. As in Krista's case, emotions of interest/anticipation, joy, acceptance, and surprise are the main primary emotions in the first phase of Eton's creativity.

Integration Phase – Secondary Emotions. During his practice, similar to moving meditation, Eton's mental elements, emotions, thoughts, and memories can self-organise into a higher order structures. For example, joy linked to the anticipation/

interest creates a secondary emotion, expectancy or enthusiasm (TenHouten, 2009), that pushes him to further exploration. Surprise connected with anticipation creates a feeling of uncertainty or sometimes puzzlement. Surprise connected with joy creates an emotion of delight (TenHouten, 2009) – the moment of being immediately and fully involved in creation.

Creativity – Tertiary Emotions. As a result of deep mediation and complete immersion in his artistic practice, Eton experiences a complex emotion I call an attraction that emerges through successful self-organisation of joy, surprise, and acceptance. This is evidenced when Eton says, "You lose track of time. It is like ego disappears if you are doing right. You are forgetting who you are…". Attraction can also be expressed as a combination of delight with acceptance, or love with surprise, or joy with curiosity. This complex emotion is similar to the experience of flow, introduced by Csikszentmihalyi (1990, 1996, & 1997). *Flow* is a period when self-consciousness disappears, and one experiences total absorption in the activity. There is immediate feedback to one's action, balance between challenges and skills; action and awareness merge and sense of time become distorted.

During his artistic practice, Eton also experiences other tertiary emotions like enjoyment in the unexpected and open-mindedness. The first one emerges as a combination of anticipation, surprise, and joy, and the second one is a combination of anticipation, surprise, and acceptance. This was evidenced when Eton says, "I challenge myself. I might surprise myself…It is interesting process, dealing with the unknown." These two emotions are expressing a readiness for surprise that means not being locked into particular way of doing or thinking but appreciating some new and surprising possibilities. It means being ready and even happy to welcome the unexpected. Open-mindedness is an intellectual virtue that involves a willingness to take relevant evidence and argument into account in forming or revising our beliefs and values. It means being critically receptive to alternative possibilities, being willing to think despite having formed an opinion (Hare, 2012). Multiple occurrences of these complex emotions may lead to the stabilisation and formation of self-identity. Eton becomes an open-minded person as suggested when he says, "I came to the realization that all art is the process – all kinds of art, whether it is realistic landscape or abstract" (see Figure 6).

IMPORTANCE OF CREATIVITY

This chapter is intended for educators, parents, and others who are interested in the emotional development of adolescents and young adults. It is the first attempt to link complexity science with theories of emotions. It appears important to bring together the insights from these areas of study in order to achieve a more integral understanding of the complex process of creativity and the emotional development of young people.

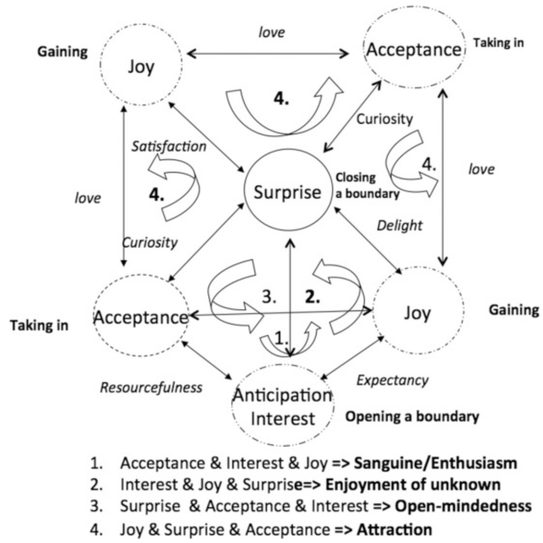

Figure 6. The pattern model of Eton's creativity.

This phenomenological study shows why it is of enormous importance to encourage creativity in schools and in general in lives of young people because:

- Creativity allows young people to learn about themselves and connects them to something meaningful; it introduces purposes and values in their lives.
- Creativity helps develop a sense of efficacy – the belief that one can make a difference, that one has the ability to coordinate individual skills and abilities in order to attain desired goals in particular domains and circumstances (Bandura, 1997).
- Creative processes, positive experiences, and formation of memories play a major role in building up new neuronal connections between the emotional and cognitive systems leading to the integration and stabilisation of emotional-cognitive structures that have an enormous advantage in confronting complex situations.
- Creativity helps young people in emotional, cognitive, and spiritual growth and empowers them to make life choices that bring joy, satisfaction, and fulfilment.
- Creativity helps young people grow into resourceful, curious, optimistic, and open-minded human beings who become open and receptive, not only to human issues, but often to the wider problems of the natural world.

CONCLUSION

Complexity science, especially the idea of self-organisation is particularly useful for modeling the coming-into-existence of new forms, patterns or structures. It allows capturing the dynamic process of creativity by focusing on the mechanisms of interactions between mental elements and their transitional features.

Through the case-study approach, I tried to re-create participants' processes of creativity over time by the close examination of their life stories, journals, and art products. The outcome of this research was the pattern models of the process of creativity. There are some unique differences among participants' individual models of creativity, but in general they share common phases such as differentiation/chaos, integration/complexity, and dissipative structures/creativity—products of creativity in the forms of new movements, new writings, and new paintings. The process of creativity of young people is intertwined with strong emotions of interest, joy, and acceptance that enhance mental activity involving global, open, and exploratory modes of attention and that stimulate thinking and enrich their imaginations. These cognitive processes then deepen emotions to complex emotions such as curiosity, enthusiasm, delight, passion, resourcefulness, and love that through reciprocal reinforcement influence their selves. Creative people become more sensitive, more open, and receptive to the internal and external world. They develop into resourceful, imaginative, empathic, and spiritual human beings.

These findings are in an agreement with Vygotsky's viewpoint that emotions are extremely significant in creative images of the adolescent:

> In this way an adolescent finds a means of expressing his rich inner emotional life and his impulses in fantasy. But it is also in fantasy that he is able to discover an effective means of finding a direction for this emotional life and for taking charge of it. (1994, p. 284)

Vygotsky believes that during adolescence, two forms of fantasy/creativity develop where subjective creativity representing the emotional life of adolescent and objective creativity is used in understanding and construction external reality. Through further development they are intertwined with each other. "Objective expression may be coloured by vivid emotional tones…" (1994, p. 285).

Finally, we can summarise that creativity is self-organising process that originates in a far-from-equilibrium state created and maintained by complex emotions such as enthusiasm, curiosity, love, passion, and resourcefulness that are the driving forces generating order and complexity in the creativity of young people. Similarly, the psychological development of creative young people is a self-organising process that implies the increasing complexity of the mental structure that differentiates – incorporates more and more elements from mental life, especially emotions, thoughts, imagination, and memories, and then integrates – construct connections among these elements. The long-term process of psychological development and the short-term process of creativity are intertwined in the cyclical, dynamical relationship. Creativity as a temporary or momentary experience/action creates conditions where emotional, cognitive, and spiritual development take place. Psychological development, on the other hand, creates the conditions for creativity to emerge by adjusting the internal environment toward openness, sensitivity, and receptivity.

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ANN GAZZARD

EMOTIONS, COMPLEXITY, AND INTELLIGENCE

Complexity theory, as described by Ambrose (2009), can elucidate our understanding of emotional intelligence, in particular its foundation in the early childhood years. In this chapter, recommendations are made for enhancing and strengthening this intelligence based on these new insights.

EMOTIONAL INTELLIGENCE (EQ)

Goleman (1995) coined the term "EQ" in his landmark book, *Emotional Intelligence*. At the time, physiological research was revealing the existence of neural pathways for unconscious emotional processing, and psychological and educational research was showing the consequences of coping with emotional difficulty or trauma and why some people may feel a choice in being able to do that and others don't. Working from Goleman's definition, the popular conception of EQ could probably be adequately described as the ability to know what one is feeling and the ability to communicate it appropriately together with the ability to get along with other people, being able to "read" well others' feelings and responding appropriately.

An equally significant conclusion from this research was the substantiation of neural networks for unconscious emotion (Goleman, 1995). That is to say the research gave credence to long-held psychoanalytic beliefs of unconscious emotion formulated in childhood and carried as emotional memory triggered by similar stimuli in the present. More recent findings in clinical fields have corroborated these physiological findings (Miller, 2001, 2009). Perhaps one of the most significant conclusions that Goleman makes drawing from the work of Joseph LeDoux is the apparent lack of involvement of the brain cortex (the thinking brain) in emotional outbursts, that is, when one is acting emotionally unintelligently. Before the work of LeDoux in 1995, it was understood that emotional processing took place first in the cortex then in the limbic system. However, LeDoux's research shows that in some cases stimuli can be first taken to the limbic system before cortical layers have time to "kick in." This so-called "emotional tripwire" is what has been used to explain the "emotional outburst," the feeling of doing something and not knowing what came over oneself in the doing.

LeDoux (1996) later explains that this can be accounted for in terms of humankind's evolution. Although he did argue at this time that emotional processing takes place throughout many areas of the brain depending largely upon the area

D. Ambrose et al. (Eds.), A Critique of Creativity and Complexity, 291–300.

of survival to which the emotion in question relates, he proposes that Man simply has not evolved sufficiently to have more of his emotion imbued with thought. LeDoux writes: "Emotions can flood consciousness because at this point in history, connections from the emotional brain to the cognitive system are stronger than those from the cognitive system to the emotional system" (p. 19).

Davidson (2012) more recently demonstrates, however, that specific forms of mental training can change this.

> Mental training can alter patterns of activity in the brain to strengthen empathy, compassion, optimism, and a sense of well-being. . . . And my research in the mainstream of affective neuroscience has shown that it is these sites of higher-order reasoning that hold the key to altering these patterns of brain activity. (p. xix)

In *The Emotional Life of Your Brain,* Davidson (2012) clearly and quite profoundly demonstrates that the circuitry of the emotional brain often overlaps with that of the rational, thinking brain. According to Davidson, "There is no clear, distinct dividing line between emotion and other mental processes; they blur into each other…., virtually all brain regions play a role in or are affected by emotion, even down to the visual and auditory cortices" (p. 89). On many occasions (resilience, context sensitivity, post traumatic stress disorder, positive/negative outlook, depression, attention), moreover, it is the prefrontal cortex (seat of reasoning) in interplay with different areas of the limbic system that makes the difference. Our perceptions and thoughts are altered when we experience emotions; both are affected by our environment. Yet, according to this research, we can use our cognitive machinery to intentionally regulate and transform our emotions and thereby our experience. The physiological research points us then in the direction of the necessity for more cognitive involvement in emotional processing, especially for purposes of warding off emotional dysfunction.

Arguments coming from the clinical field in psychology corroborate these findings and attest also to the necessity of a more strident cognitive involvement for the resolution of some clinical disorders. Greene, for example, has worked intensively with Oppositionally Defiant children and asserts that part of what being a therapist, teacher, or a helping parent entails is becoming the child's thinking brain. At a therapist training workshop conducted by Greene at University of Pennsylvania in 2001, he argued that we have to "find out what the child is thinking that he shouldn't be, and what he's not thinking that he should be," and accordingly, start training his thinking. According to Greene, we have to become the child's "surrogate frontal lobe" whereby the child can be helped with skills like, staying calm in the midst of frustration, problem-definition, anticipation of problems, generating alternative solutions, taking another's perspective, "seeing" the big picture, interpreting accurately, finding language to match individual and situational needs, and altering cognitive biases, for instance (p. 14).

As another clinical example, the work of Miller further corroborates these trends and confirms the neural basis of an emotional unconscious. In summarising more recent brain research of Joseph LeDoux and others, Miller (2001) writes:

> The consensus is that early emotions leave indelible traces in the body and are encoded as information that will have a serious impact on the way we feel and think as adults, although those effects normally remain beyond the reach of the conscious mind and logical thought. (p. 118)

Miller (2001, 2009) argued cogently from a psychoanalytic and therapeutic perspective that the conscious mind *can,* however, be brought into play but not until after the often very painful experience of confronting early childhood experiences and "re-feeling" them occurs. Until then, she argues, the memories stay repressed and serve as a barrier in the mind to live a more fully conscious life in the present.

Clinical psychology, then too, provides evidence for the necessity of cognitive involvement in correcting and perhaps preventing certain behaviour and emotional disorders, and both clinical and physiological findings support the psychological tenet of an emotional unconscious whose structure and dynamics are laid down primarily in early childhood.

THE DEVELOPMENT OF EMOTIONAL INTELLIGENCE

It seems at face value that an effective way to enhance emotional intelligence would be the use of strategies to stimulate the reasoning processes (brain cortex) especially about the emotion when the emotion is happening. Indeed, an argument for the role of philosophical and creative thinking in the development of emotional intelligence has already been made (Gazzard, 2001). Briefly the proposal is that, in light of the apparent absence of cortical feedback at times of emotional distress, early childhood is the place to begin engaging children cognitively with the emotion in question. That is to say, walking around the block when one is angry may prevent actions one might later regret, but in and of itself it does little to deepen one's understanding of one's feeling or the situation in which it occurred. Rather creative or philosophic engagement with the problem at the time of its inception and duration holds more likelihood of such an outcome, particularly if this is encouraged in early childhood. The use of color and art, for example, to express emotion, the use of poetry and writing to communicate feelings, and the use of drama and role play are all ways children can be encouraged to release emotions as they are happening.

The problem though is that "life happens," and even the best intended parenting and best early childhood educational environments leave traces of unconscious emotional memory that serve to drive later behaviour. It is here that some constructs drawn from complexity theory might shed some light. But first, a few words about conditioning.

THE PROBLEM OF CONDITIONING

Readily we accept the reality of the behaviourist principles of conditioning when it relates to overt behaviour. Less readily do we accept the same phenomenon when it applies to our thoughts and feelings. Yet we do not have to look far to find examples. The formation of prejudiced attitudes conditioned by family upbringing is a case in point. Conditioned fear is another that is discussed abundantly in the psychological literature and, although it may be more easily seen in the case of more basic emotions like fear, the role of conditioning is equally if not more relevant in more complex states like envy, greed, love, and resentment. Would we love and hate different people and different things if we were raised in a different family or a different culture? Surely this is one of the things Kohlberg was discussing in his Post Conventional Level of Moral Reasoning. Although he was working within the framework of moral development, it is being able to consider oneself outside the bounds of one's culture that enables one to see the delimitations it has placed on one's identity in general, not just one's moral self. If Vygotsky is correct, moreover, in claiming that thinking is internalised dialogue, then the quality of thinking that takes place around emotional issues is going to be well established early when basic emotions are first experienced. Communication at these times that is fraught with negativity, blame, negligence, and so on, leaves little room for the conditioning of thinking in the child that itself is not entrapped by equally biased and detrimental patterns.

Applying the chaos-order continuum to parenting styles, we find at either extreme, as predicted by complexity theory, conditioning that is inhibiting to the child's growth potential. At each extreme we find evidence of abuse. Whether it be from neglectful parenting (chaos) at one side or authoritarian parenting (order) at the other, the long term crippling potential of each on the child's intellectual, emotional and physical flourishing is well established. The effects of abuse are so powerful as to be even able to override the effects of genes. Davidson (2012), for example, reports on two studies showing that the presence of the aggression gene or depression gene leads to no greater manifestation of either unless there is also the presence of an abusive childhood environment or stressful event in late adolescence respectively. In both cases the gene needed a challenging environment to get switched on. Parenting then that falls midst the continuum, namely, authoritative parenting is certainly more desirable. Good fortune and/or the opportunity for parenting education can secure this. Relying on either, however, is a somewhat haphazard approach to serving our young. What skills might we develop in our young to help them navigate the complexity of understanding required for successful passage through the emotional fabric of their lives, in particular the emotional crucible of the family environment? How might we support them best in their search for the emotional stability as well as the emotional flexibility required for tolerating the inevitable flow of their own emotions and the vacillation within the emotional environment between situations that are at one time unpredictable or meaningless and at others, boring or punitive?

In other words, how might we help them establish a sense of self that is stable, yet flexible enough, to withstand the tide of emotions rising forth from both within themselves and from others in the environment? What might be that quality, trait or dimension of self that sits at the *edge of chaos* enabling a more promising and productive outcome for both the individual and the society? Alice Miller, I believe, leads us in the right direction.

THE WITNESS

Miller (2001) introduces the concept of "an enlightened witness" as part of the solution for addressing the recalcitrant conditioning that often remains unconsciously directing behaviour. An enlightened witness is somebody (teacher, therapist) who has been through the difficult process of getting in touch with blocked feelings from childhood. Such a person can guide others most successfully through the barriers of their own conditioning. Being already familiar with the defensive tricks the mind can play, an enlightened witness can observe for the other, his/her emotional blindspots and help guide him/her with alternative cognitive frameworks.

It is this concept of "an enlightened witness" that I believe we can adapt for our purposes here. Used herein then, "the Witness" will refer to an aspect *within* the person that can be developed over time through training, practice, and effort. It refers to an ever-present, if possible, aspect within one's self that, as proposed here, sits at the *edge of chaos* helping people appreciate the complexity of conditioning on their psyches. It is the part of the person that can observe the behaviours stemming forth from the thinking self, the feeling self and the instinctual self with equal objectivity. Providing a vision of neutrality from which a more objective, less attached, less conditioned response can be formulated, the Witness provides the space that allows for a behaviour of *choice*. It is not that part of the self that judges one's behaviour by putting it into categories and then labeling it with negative or positive attributions, but rather the Witness is that part that merely "sees." The "judge" is usually part of the conditioned self. How could it otherwise derive its notions of right and wrong? The Witness, however, is culture-free, family-free. It is the place from where conditioning can be seen. If as LeDoux reports, emotion has much to do with the interpretation (cortical brain) of the felt experience, then how we have learned to understand the feeling contributes largely to what we ultimately experience as the emotion. Yet, even here, we are still left bound by the paradigm within which that understanding was shaped. It is the Witness that has the potential to allow a fleeting glimpse of the whole drama and the conditioning paradigm by being momentarily outside of it.

With this increasing ability to distance ourselves at any particular time from life's drama and our role in it, we also enhance authentic communication with ourselves and with others. Is there not a smile that can come in the midst of an argument with a loved one, when both persons recognise "the game" being played at that moment? The freedom that comes from being able to interact and communicate from a part of oneself not confined to whatever the drama is demanding of one's psychophysical system at any given moment is a rich source of creativity. Opportunities for different ways of responding intellectually, emotionally or behaviourally can present themselves when the felt obligation of conditioned patterns are lifted. Creativity walks hand in hand with the opportunity to embrace choice.

The development of Witness awareness contributes also to a growing compassion. As it fosters an appreciation of the power of the environmental conditioning process on our being, it becomes easier to look beyond that to the person inside the other whose journey (conditioning) we more readily see. Compassion can blossom by recognising others, as persons struggling to overcome aspects of their own conditioning.

Living in and from within, the whole conditioned (good or bad) psychophysical self renders feelings of powerlessness to act, be or feel differently. *Entrapment* can be as subtle as it can be gross. Whether one can change one's life or not and whether one would want to or not both raise philosophical concerns; however, the question still remains how to be happy inside the life one is living and inside the psychophysical unit through which one is experiencing it. The Witness is the doorway to this possibility.

This concept of the Witness is, we must admit, essential and has been overlooked in discussions of EQ. The development of the Witness allows the upward movement through increasing understanding of the complexity of the psychophysical drama to *the edge of chaos* and the pinnacle of *seeing*. The upward movement is not necessarily smooth or easy (and means of achieving it will be discussed in what follows), but the flashes of insight that come from this *edge*, can guide more intelligent future actions. Even though momentarily one may be swept back into the drama, this new view from *outside* can serve to lessen the attachment to the felt necessity of conditioned responses. Perhaps this is more what EQ could be and perhaps new goals for EQ could be stated along the following lines.

EQ is the ability to observe one's self seeing underlying motivations, intentions, desires and inhibitions that frame one's behaviour. It is the ability to experience that part of one's self that enables this and that is, at the same time, not them, but rather is free of them all. It *sees*, aware as it does, that it is not what is *seen*. Together these faculties enable the freedom of personhood that is the birthright of humankind. It is not so much the nature of the conditioning that is important, as it is to be able to recognise the process within ourselves and not mistake who *we* are for what *it* is. Strengthened by the honesty of self observation, the development of a sense of self that is less identified with these observations will emerge; a sense of self not so readily affected thereby by the fortunes of fate.

Not to be mistaken, the regulation of a lot of emotion, in particular negative and destructive emotion, is beneficial and can lead to more intelligent emotional behaviour. The question though becomes whether therapeutic devices that serve to regulate emotion, like cognitive reframing, can be considered appropriate *goals* for EQ. Indefinite reframing of situations is possible but does this adequately define the development of emotional intelligence? Where, for example, is the self? Which frame might it represent?

THE WAY FORWARD – ENABLING CONSTRAINTS

What then is needed to strengthen the areas of the brain now known to be useful for regulating emotion as well as those contributing to the development of this Witness phenomenon? Let us first return to where we began with the physiological findings.

As previously discussed, the activation of the left hemisphere of the brain, in particular, the left prefrontal cortex (underlies positive emotions) as well as the formation and strengthening of connections from there to other parts of the brain (sustained positive emotion, resilience) is important for emotional regulation. So how can we activate these areas and connections?

According to Davidson, “The prefrontal cortex was, and is, known to be the site of the highest of high-order cognitive activity, the seat of judgement and planning and other executive functions” (p. 69). But what about the left prefrontal cortex? Recent work in cognitive neuroscience has shown that the long held right-brain, left-brain distinctions with respect to cognitive function may not be so distinct. That is to say, some cognitive functions like those involved in visuospatial ability, for example, may be more generalised across both hemispheres than previously believed, and individuals neither right-brain nor left-brain dominant (Kalbfleisch & Gillmarten, 2013; Nielsen, Zielinski, Ferguson, Lainhart, & Anderson, 2013). Very interesting for our purposes here, however, are some of the findings of the latter mentioned research (Nielsen et al., 2013). On the one hand, classical language regions of the brain consistently showed strong left lateralisation, but another hub (group of core brain areas) also showed left lateralisation. In a diverse assortment of cognitive tasks, this latter hub showed greater activity at rest. The proposal is that this left lateralised area of core regions may be involved in attending to internal stimuli, internal narrative, or self reflection, with further suggestions that this network may be active during self-referential thought and memory of past events.

In light of these findings, stimulation of the brain with creative, philosophic and puzzling ideas is implied, especially if the opportunity for dialogical engagement also exists. Activities like these that promote reflection, inquiry and critical thinking (once held to be a left hemisphere function) can be used as tools for self-reflection and self-inquiry when the topics under investigation are one’s own emotions and the emotional situations in which one finds oneself. When self-reflection and self-inquiry are done when the emotion is happening, moreover, they serve as tools for strengthening connections from the cortex to other brain areas (amygdala, etc). Indeed, Davidson gives the following example as one of two recommendations to train the brain to develop a “positive outlook” (p. 230).

The recommendation is to place oneself in a situation that arouses a desire (emotion) that one is perhaps trying to modify and, while in that situation, resist succumbing to the desire while mentally planning (prefrontal cortex) how one will allow oneself to partake at some point in the future. The example Davidson uses here is perhaps a little confusing because of his use of desire, instead of one of the more basic emotions. Paul Ekman's seminal studies on basic emotions and cross cultural facial expressions led to the identification of six basic emotions that are recognised universally: happiness, anger, sadness, fear, disgust, and surprise (Ekman et al., 1969). Perhaps, then, the example could be better understood by considering a toddler who after being dropped off at preschool becomes upset and sad and starts crying (emotion). At this time, the suggestion could be that the teacher sit with the child and encourage her to think (prefrontal cortex) what she would like to do with her mother when she sees her next. Perhaps they can enjoy making a list (planning-prefrontal cortex) of all the things they might do together when mother collects her later in the day. Here we have stimulation of the cortex about the emotion while it is happening (connection of cortex, perhaps left prefrontal cortex, to relevant brain part, the amygdala).

The dialogue and/or activity used to engage the child cognitively at the time of the emotion must be constructively meaningful about the emotional experience *for the child*. That is to say, it is *the child's* cognitive engagement that is crucial.

Whether it be child or adult, however, the processes involved remain the same; creative cognitive engagement with the emotion at the time it is being experienced. Philosophic inquiry would be one suitable possibility here, as too would arts activities (Gazzard, 2001). Philosophy is well known for the complexity of nuanced thinking it demands from those who explore the problems it poses. Characterised by enjoyment derived from increased understanding as opposed to definitive solutions, its pursuit is sustained by an enrichment of life experience. Parents and teachers who can deepen a child's understanding of his/her experience, emotional or otherwise, by engaging the child in creative dialogue about that experience also serve as good role models of EQ. They activate the cognitive neural machinery with dialogue and discussion that is as much logical and analytical as it is intuitive and imaginative, and in so doing facilitate the child's/student's access to his/her own emotions. Arts activities, moreover, can do the same. As a child is trying to figure out (prefrontal cortex) which animal best fits how he is feeling (anger/mad) and the right costume to express it creatively, his thinking and understanding about the emotion are being refined through processes like discernment and analogical reasoning, to name a few.

Activities such as these stretch the individual's (adult's or child's) tolerance for ambiguity and his/her ability, thereby, to suspend judgement be it decision or action. Becoming more sensitive to the subtleties of meaning that permeate all situations, individuals trained in this way have more hope of navigating and transcending the maze of conditioning. Actions and decisions become more a set of possibilities as opposed to, at the other extreme, a set of predetermined actualities. Being more at ease with the many shades of gray that lie between the extremes of conditioning discussed earlier, behaviour that is at one and the same time appropriate to the circumstances yet joyful because of there being more options, can be achieved.

Davidson (2012) does not address “the Witness” per se, although of the six dimensions of emotional style he describes, four speak directly to it. They are attention, self awareness, social intuition, and sensitivity to context. And of these four, the first three have methods known to activate the relevant brain areas.

One of the methods, described as beneficial for each, is mindfulness meditation. Mindfulness meditation is a form of meditation where one practices moment to moment, nonjudgemental awareness. The awareness may be of breath, body part, external object or something like, in the case of social intuition, social cues. Davidson gives a detailed description how each of these dimensions of emotional style is affected by mindfulness practice. What is important to note here is that just as training the mind in the practice of deliberative inquiry runs counter to the mind’s habit of running untamed along its conditioned path, so too practices of meditation and concentration run counter to unbridled, conditionally dictated expressions of self. The focus afforded by such efforts serve to reign in the dancing mind not to inhibit constructive flights of imagination but rather to facilitate a more stable sense of self from where insights into bodily, emotional and cognitive phenomenon can come. Moreover, mindfulness practices are equally accessible to both children and adults.

In conclusion, we could probably best summarise the constraints that best enable movement upwards (increasing EQ) through the *zone of complexity* to the Witness at the *edge of chaos* as follows:

- Mindfulness practices to facilitate, strengthen and refine observations of self and environment;
- Self-reflection and self-inquiry to foment the de-conditioning; and
- The development and practice of logical thought processes required of inquiry to pierce through the tale that conditioning might otherwise tell us and have us believe as true.

Perhaps more important and advantageous than any of these, however, is the good fortune of an emotionally intelligent early childhood environment, particularly if Miller is correct. An environment where adults model honest self-observation, self-reflection and constructive behaviour that provides opportunities for creative emotional expression for their children is a potent means to secure in children capabilities for successfully navigating the mosaic of human complexity. On this view, parent training workshops would be an ultimate tool in service of a more emotionally intelligent society. Parental education could easily enhance the prevention of some of the mishaps in upbringing and communication with young children that often leads to much remedial work in later life. If Goleman is correct when he asserts that success (by American standards) can be accounted for by 80% EQ and 20% IQ, then it behooves us as parents and teachers to make rapid use of those research findings suggesting solutions (Goleman, 1997). Not only will the society benefit from having happier, more creative citizens, but its members will have the opportunity for more meaningful lives.

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