Running The Course:
Complexity and Enactivism in Education

by

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Recent findings in complexity theory and enactivism have a relevance on how we view and teach children. In this study, 10-yearold children were taught the basics of complexity theory using improvisational writing, theatre sports, and fractal geometry over a 6-month period. The curriculum was framed in an extemporal methodology based in complexity theory (specifically drawing on chaos theory, systems theory, and emergence). An enactivist theory of cognition, whereby knowledge is seen as a complex process involving learners, teacher, and environment—rather than a reductionist project of inputting information into learners—was the basis for final appraisal of student learning. The outcomes of the study suggest that complexity and enactivism might serve to inform both the content and the structure of curriculum—in the process, rendering visible many of the reductionist and untenable assumptions that infuse much of conventional teaching.

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Acknowledgments

This body of work has not emerged from myself in isolation. The "knowing" that evolved to support the study came from many sources but incredibly astute and meaningful guidance was provided throughout by Brent Davis. Karen Meyer was instrumental in initiating my study in the direction of enactivism early on and in providing fresh observations during the final revisions of the work. Susan Pirie provided a thoughtful perspective on many of the final conclusions. The Vancouver School Board also provided permission to conduct the study in one of their schools—their support of educational research is appreciated. In addition the whole study was only possible with the involvement of the students of my classroom. The support they and their parents provided to immerse ourselves in this study is what made it possible at all —many thanks to everyone.

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A large part of the socio-cultural expectations of an era is born of the prevailing scientific (or religious) paradigms. In the "Modern Era," theorists such as educational researcher Ralph Tyler and behavioral psychologist B.F. Skinner—persons whose thinking was highly influential in the mainstream of curricular thought during the 1960s and 1970s —took their underlying assumptions directly from the philosophical and scientific theories of Sir Isaac Newton (1643-1785) and René Descartes (1596-1650) (Miller and Seller, 1990). As Fritjof Capra (1996), a student of the "new" physics (which has emerged in recognition of the inappropriateness of Newtonian Mechanics' long standing dominance of academic discourse and research) explains:

> Descartes based his view of nature on the fundamental division between two independent and separate realms—that of mind and that of matter. The material universe, including living organisms, was a machine for Descartes, which could in principle be understood completely by analyzing it in terms of its smallest parts. (p. 21)

Descartes and his contemporaries are now regarded as the primary architects of modernism—that is, of that world view that sees all happenings in terms of reductive linear relationships and causal logic. New scientific theories have come to light though that displace Newton's and Descartes' clockwork models of the universe and the mind, offering in their place more dynamic, implicating, and complex notions. These "postmodernist" concepts prompt a need to question the transmissive approaches to teaching and analysis that are supported by (and that, in turn, support) modern age doctrines.

Born in 1955, my lives as a student and as a teacher have overlapped with the now-pervasive movement to reveal and to move beyond the limitations of the modernist perspective. My own experiences have led me many times over to question the simplistic chunking up of information that defined my schooling experience, and I have tended in my own teaching toward a more integrated approach than the fragmented models that were offered me. I have come to call my preferred teaching style—and perhaps my own life and learning styles—"extemporal." *Extempore* is that which arises from improvisation—the unpremeditated, unrehearsed action born of and borne by the circumstances of the moment. With regard to teaching, an extemporal approach recognizes that learning emerges in the moment from the context, and it can not therefore be overly prepared, studied, and readied beforehand. As Davis (1996) explains, for example,

> William F. Pinar and Madeleine Grumet have reminded us of the verb *currere* from which "curriculum" ... is derived. *Currere* refers to "the running of the course" rather than the "course to be run, or the artifacts employed in the running of the course."(p. 90)

This is not to say there is no plan, no desire to impart certain concepts, but that there is a willingness to be open to the process and not bound by procedure. The same attitude has been described by many curriculum theorists.

Beginning in the late 1960s and early 1970s, a varied collection of educational theorists sought to open the established field of "Curriculum Studies" to a broader interpretation of curriculum. These theorists sought to move curriculum away from the conception of courses that are pre-set by distant authorities—ones based in a modernist frame that students must "run" well to succeed — to one where students and current conditions had more influence. These theorists differed in many ways, but were alike in their desire to address the limitations of a reductionist curriculum. Now known as the "Reconceptualists" (Pinar, 1988), these theorists debated the merit of the Tylerian curricular models of the time (that is, rigid, pre-specified, goal-oriented courses of study), pointing out that they "ignore what takes place within the experience of the teacher and learner in a dialogical setting" (Padgham, 1988, p. 360). The Reconceptualists were successful in many of their endeavors, particularly in terms of the articulation and advocation of "constructivist" epistemologies for the classroom.

The movement did not end there, however. Curriculum theorist Janet L. Miller (1996), for example, has suggested that there may now be a "second wave" of reconceptualization, emerging as much of the theorizing of the first wave is now coming to be enacted in classrooms. She calls on researchers to keep in mind that the point of reconceptualizing the curriculum over the past 20 years has been to "move the field away from its long-standing managerial, technocratic and positivist orientation, and toward a multi-valent, multi-vocal, multi-perspectival theorizing of curriculum" (p. 6). Miller reminds us that change and divergence are integral and ongoing aspects of society—and, therefore, of curriculum. In endeavoring to continuously reconceptualize the nature of curriculum, the desire for a singular "right way" to do things must be set aside. Instead, what becomes important is the process of questioning suppositions and uncovering the hidden ground of activity.

Two areas of postmodern research that support teaching and curriculum-making as extemporal processes are the areas of *complexity theory* and *enactivism*. Recent research findings in these areas clearly refute the notion of a mechanistic universe, offering instead a strong body of evidence for a view of the world (which includes the human mind) as emerging from a multitude of complex processes (Capra,1996; Waldrop, 1995; Varela, Thompson, and Rosch,1996). As Capra explains, the movement is widespread:

> Different scientists call it by different names—"dynamical systems theory," "the theory of complexity," "nonlinear dynamics,'" "network dynamics," and so on. Chaotic attractors, fractals, dissipative structures, self-organization, and autopoietic networks are some of its key concepts. (p. xviii).

These findings reinforce that curriculum, when viewed and taught as an integrative whole and not a reductionist puzzle, is in greater synchronization with the lived-world. Complexity theory, enactivism, and their related discourses thus support a conception of curriculum that embraces the potential for change and that seeks to be mindful of current socio-ecological realities in ways that modernist, "back to basics," transmissive models cannot.

As yet, few of the insights attained by the researchers in complexity theory or enactivism have found their way into pre-university classrooms, either to inform teaching or as a direct topic of study for the students. So it is here as an educator and a researcher I chose to situate my research and questioning: In this shift away from the need to prove the world to be a predictable, mechanical place and toward an embracing of a more organic and fluid view. The study took up the task of teaching a group of grade five students the basics of complexity theory via an integrated curriculum that was planned, taught, and interpreted with enactivist sensibilities.

The thesis is divided into five chapters and is organized as follows:

1) Introduction: Changing World Views
   - Personal Perceptions: Forest Days
   - Theoretical Considerations:
     Complexity Theory,
     Systems Theory, and
     Enactivism
   - Curricular Links:
     Fractal Geometry,
     Theatre Sports, and
     Teaching and Learning Complexly

2) Designing a Complex Curriculum
   - Linear Versus Recursive Planning
   - The Activities:
     Process Writing,
     Theatre Sports,
     The Stone Game,
     Fractal Geometry, and
     Logo Programming
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3) Enacting and Emergence of a Complex Curriculum
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     Logo Programming,

- Bringing It All Together

4) Interpreting a Complex Curriculum
- Complexity
- Extemporal Moments

While this structure looks very linear, the teaching, the research, and the writing were in fact very recursive in nature, demanding constant reformulation and reinterpretation with events and understandings continuously folded back onto one another.

Chapter 1
Introduction: Changing World Views

Personal Perceptions: Forest Days

From my current place in life, my involvement and attraction to the subject of complexity theory seems to me to have unfolded from my own chaotic and complex array of experiences and knowings. These are not easily encapsulated into a brief statement, but I feel some personal background is relevant to the study.

Prior to becoming a teacher, a career decision that had the effect of locking me into one school district, I was a nomadic sort of person. Graduating into adulthood in the post-sixties, but still inspired by the exploratory attitudes of that decade, I traveled a great deal in my twenties and early thirties. I tried my hand at several different occupations, from Street Theatre Performer to River Ferry Operator to Park Ranger. I lived in a variety of places, from large cultural and urban locations such as London, England, to an isolated and rustic cabin in the Fraser Canyon of British Columbia. Throughout this time I was always an ardent reader, straying through a range of literary texts and college courses on subjects ranging from geology to French literature to theatre. I would not have called myself directionless. Rather, I was more a person who was interested in everything, excited by all the opportunity life had to offer—a "generalist" in those days; perhaps a "complex personality" in these.

It was in one of these later incarnations that I began my life as a park ranger. From 1986 until 1990 I spent many hours each day walking and working in a coastal rain forest—spending many hours by myself. An event from that time is exemplary of the shifts in awareness that were occurring for me, in part because of the privileged access to such a magnificent natural environment.

One day while sitting, looking over a part of the forest at a hazy summer sky, I became aware that there were no real separations between or among all of what I was seeing. For a moment, instead of perceiving distinct separate entities—an ocean, a forest, a sky—the world around me was a cohesive, yet moving pattern. The delineations between water and air, fish and birds, trees and kelp, shifted—and while I was aware of them as entities, I was also keenly aware of how they blended and were versions of one medium. I became conscious of the similarities in operation of the various agencies within the continuum of "Earth." For a moment that day, I felt that birds and fish were kindred in their movements—as were crabs and humans. Suddenly I was caught with the notion that the air I was moving through and inhaling was a lighter version of the ocean where the fish swam. And that air may have come from the ocean, or might have recently been reconstituted by the forest. The categorical lines from the deepest ocean to the upper stratosphere were blurred and I came to perceive transitional zones in the same system where before I had seen separate categories.

Ecologist and philosopher David Abram (1996) writes of similar shifts in perception. Drawing from his experiences with Balinese peoples and his time in the eastern Bali, Abram suggests:

> If we dwell in this forest for many months, or years, ... we may come to feel that we are a part of this forest, consanguineous with it, and that our experience of the forest is nothing other that the forest experiencing itself. (p. 68)

Existentialist writers, such as Jean-Paul Sartre and Maurice Merleau-Ponty, have also written of the experience, as have many writers and thinkers from Eastern traditions. But, that day it was my own experience and, for me, it was original and unique.

The experience altered the ways I perceive the world and discern how it is categorized—and while I have drifted back to my urban way of generally noticing the sky as the sky and the ocean as the ocean, the sense that the world can be other than how I conceive of it as has never completely diminished. What has remained with me is a sense that we decide as a culture to categorize in a certain way, but it is not the only way. It just is a way; it is defined by our lineage of modernist sensibilities and it is likely flawed in its negation of the collectivity of our existence. As those sensibilities and collective agreements change, so do our manners of perception. From a random background of possibilities, we pick what is significant to us in the ways that we interact or couple with other aspects of the world. Varela, Thompson, and Rosch (1991) note that "over time this coupling selects or enacts from a world of randomness a domain of distinctions" (p. 157). We decide and define what is relevant from the randomness of life, in the process, defining our relationship to it.

The perceptual shift I experienced is in some way indicative of a larger shift that seems to be occurring to people across many fields—from economics to physics to psychology. The transitions in each domain are based on the realization that the modernist paradigm has missed out on the importance of the role of intermingling matter—the same matter that I pass through daily but stopped and noticed in the forest that day. Physicist Ilya Prigogine, in looking at how the world orders itself, noted that chaos and coemergence were critical components of the process that were not included in the classical physics of the Newtonian paradigm. As curriculum theorist William Doll, Jr. (1988), explains

> The new order is filled with spontaneous transformations, strange attractors, bifurcation points and autocatalysts ... these concepts are part of the unstable and turbulent state Stephen Jay Gould, Douglas Hofstader, Thomas Kuhn, Jean Piaget, and C.H. Waddington have been studying. (p. 125)

In response to the findings of these researchers and many others, a number of well established experts from varied fields came together in the mid 1980s, to compare ideas about research discoveries that diverged from the Newtonian way (Waldrop, 1992) in their recognition of life as an ever evolving process. They formed an organization that is now known as the "Santa Fe Institute" and gave the name to the field of Complexity Theory. It was in complexity theory's subsets of chaos theory and fractal geometry that I made some of the more meaningful (to me) theoretical connections between much of my own perceptions about life and an academic theory. This study then grew from there.

Theoretical Considerations

Complexity Theory

The discoveries of those involved in the Santa Fe Institute are far reaching spanning fields as diverse as economics and physics. The theory has thus evolved from several different radix, resulting in many ways to approach a study in it. In terms of this particular study, the two most influential aspects are those of *chaos* and *systems theory.*

Chaos theory has been applied to the study of weather patterns, stock market trends, biological systems, artificial intelligence development, and physics—just about anywhere that people are attempting to understand how systems operate (Gleick, 1987; Hall, 1991).

The field opened up with the advent of computer technology. The computer provided a tool to explore patterns of change (chaos)—as opposed to patterns of stability—with a speed and accuracy that had never previously been available. Meteorologist Edward Lorenz was a pioneer in the field, creating weather system model in the early 1960s that facilitated the understanding that small changes in a system can ultimately lead to large alterations. This finding has become popularly known as the *butterfly effect*, based on the semi-serious notion that when a butterfly flaps its wings, it creates changes in the air currents that can potentially trigger a storm. The implication is that, while small and gentle, the actions of a butterfly combined with the various elements of an active system, like weather, can trigger emergent conditions unseeable when the butterfly's actions are considered in isolation. Lorenz's own findings occurred accidentally when he reset a weather simulation program that had been running for some time. When the program crashed he reset it, but thinking it would make no difference, chose to round the original number off the second time. The resulting simulation was dramatically different from the one he had set up the first time (Capra, 1996; Gleick, 1987; Hall, 1991).

Given the state of computer technologies in the early 1960s, the Lorenz program was only numeric and, hence, accessible mainly to persons adept at mathematical calculation. By the 1980s, computer interfaces had become much more graphic in nature. That transition enabled the emergence of mathematician Benoit Mandlebrot's *fractal geometry* (see Figure 1), which demonstrated a number of concepts from chaos theory in a much more accessible way. Prior to the era of the home computers, beautiful mathematical forms such as the butterfly effect, strange attractors, self-similarity, and points of bifurcation were numerically unwieldy, and therefore inaccessible to the lay person.

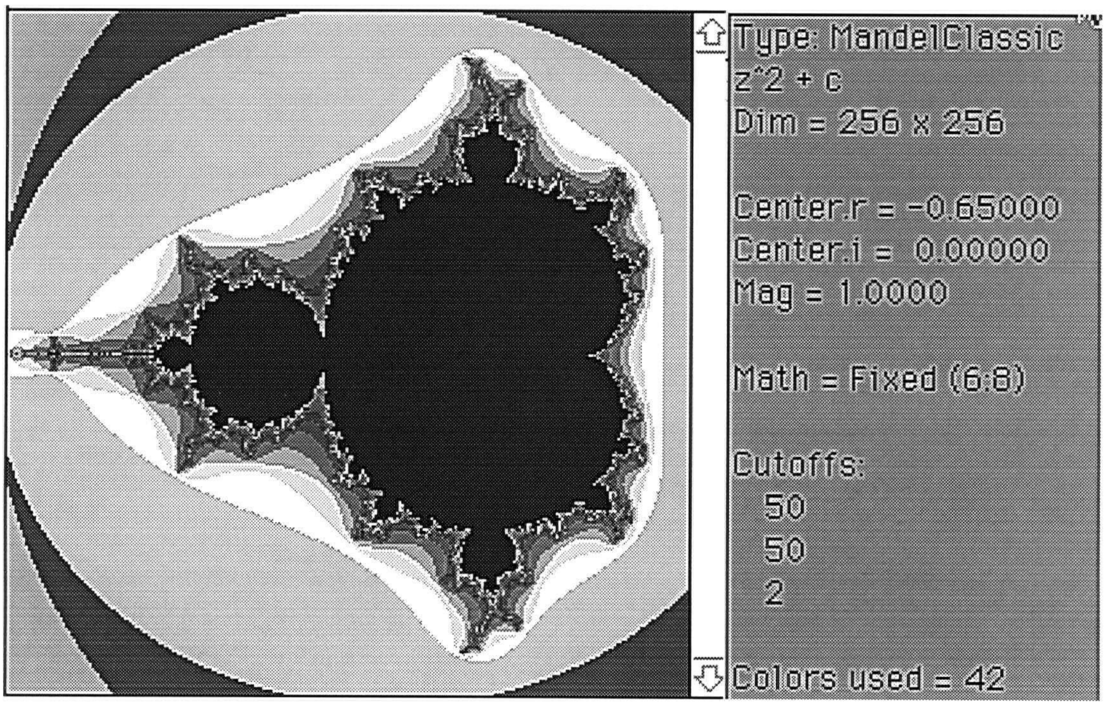

Figure 1: Mandelbrot Fractal

(created using the Program *Mandella*, by Jesse Jones, 1990)

Fractal models are now used to simulate and to demonstrate approximations of the geometry of the living world. The image presented in Figure 2 is an example of one way the program is used. It is a mathematical model that mimics the natural form of a sea conch or perhaps a storm formation. Even though it resembles a drawing done by an artist, I created it by "zooming into" the Mandelbrot set.

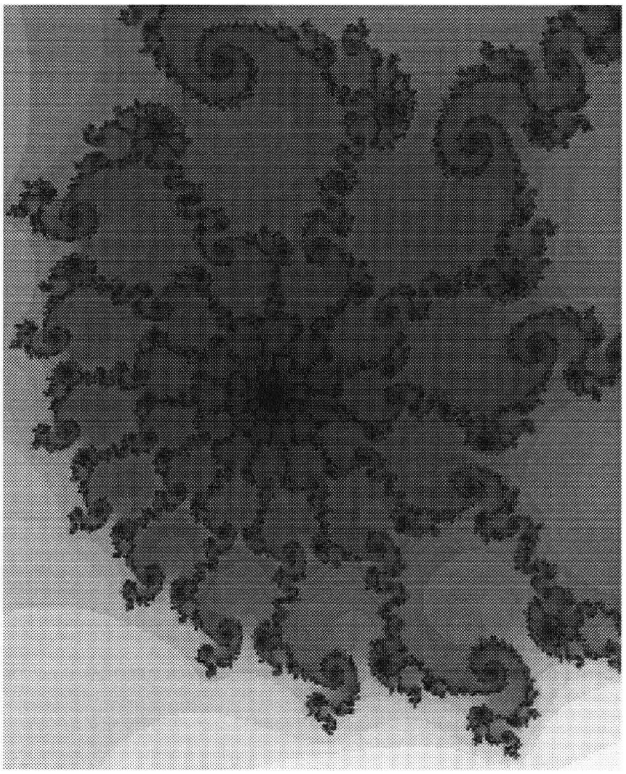

Figure 2: Section of Mandlebrot Fractal

The fractal imagery and formulae allow a reflection of the environment more akin to how we perceive it, without the rigid perfection of traditional geometry. A key aspect of this geometry is a quality now known as *self-similarity*—a notion that points to the way that, within nature, many shapes come very close to repeating themselves inside the system they are in. A mountain looks very much like the rocks within it, for example. The branches of a tree often look like the tree itself; ocean waves contain smaller waves. (Slight variations in pattern are attributed to the butterfly effect.) By way of illustration, Figure 3 provides close-up look at a section of the Mandelbrot Set shown in Figure 1. It demonstrates that, within the whole (Figure 1), there exist smaller self-similar versions.

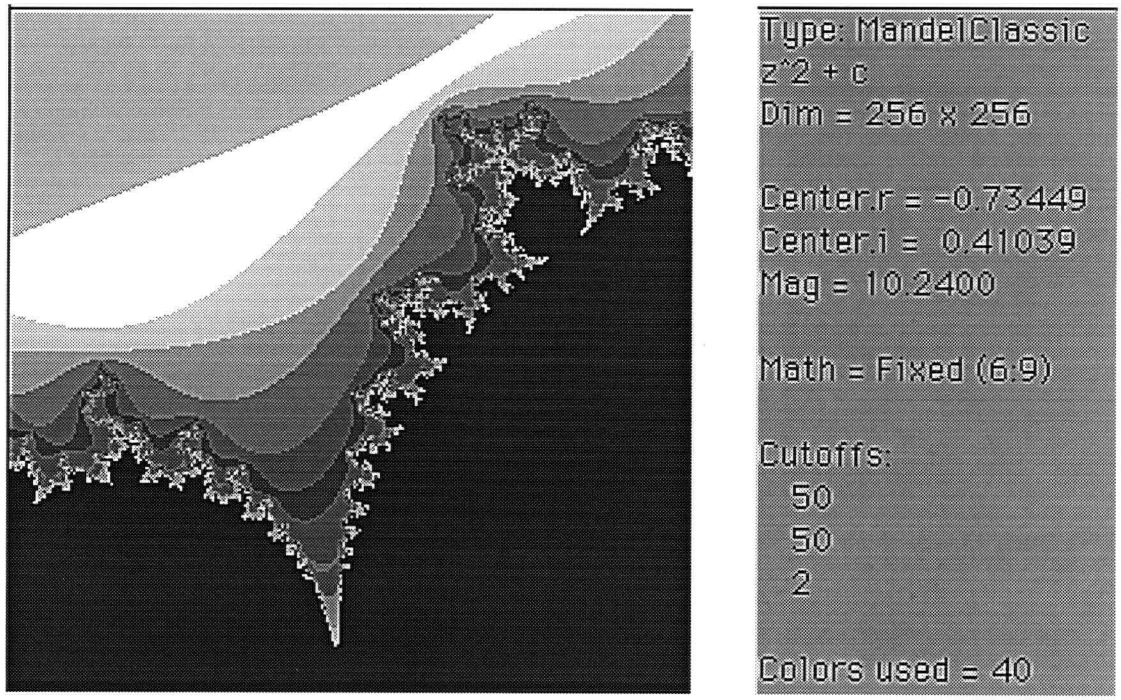

Figure 3: A Zoom into the Mandelbrot Fractal

(created using the Program *Mandella*, by Jesse Jones, 1990)

This manner of similar patterning will reoccur in what seems to be an infinite way when "zooming in" on the image of the Mandelbrot set. It bears noting that the inputs to the mathematical formula have changed from Figure 1 to Figure 3 as part of an iterative process whereby the input at one stage is determined by the output at the previous stage to create this effect.

In terms of the world I have worked in outdoors, I find the idea of self-similarity, considered as an analogy to the relational structure of the biosphere, to be useful in making sense of my observation as a park ranger that, in the forest, there were profound similarities in the patterns I was seeing, and yet there were profound differences. The pattern in the ocean of some agents moving through the fluid aspect of the environment using body movements (fish swimming) and others moving about on the more solid aspects by lifting off and settling again (crabs crawling) was repeated in the middle atmosphere with other agents using body movements to fly and others lifting off and settling again—walking. While there were similarities across the systems of the air and the water, the inputs were slightly different. Hence there are differences, arising from the need to accommodate to contextual difference while apparently constrained by the same sorts of structural possibilities. The recursive aspects of fractal geometry are applicable in that there is a similarity of pattern that is demonstrated not just in the human scale (e.g., rocks, trees and clouds) but also in the larger biological patterns of the planet.

Computer-generated fractals provide dramatic graphical representations that illustrate and demonstrate such ideas as the butterfly effect and self-similarity—and, in fact, it appears that the presence of powerful computational devices (in the form of the modern computer) were necessary for the emergence of fractal geometry. But much simpler, non-computer-based fractal figures or structures can be used to explore these concepts. Among the possibilities for hands-on investigations is the collecting of samples from the natural world—twigs from trees, broccoli or cauliflower stems, or even rocks—each of which demonstrates the same pattern in smaller and smaller versions. The basic principles of fractal geometry can further be demonstrated by folding and cutting paper. These sorts of activities provide a way into a kind of mathematics and computing that simultaneously highlights the fluid diversity of the world while pointing to the stable and interrelated patterns it manifests. Moreover, with a proliferation of informative and non-specialist shareware and articles, the subject is accessible to "lay people"—including myself, and therefore, to my students.

Systems Theory

Fractal geometry links to—and is actually one of the forerunners of—systems theory in its concerns with patterns of organization and with what prompts change and sustains stability in them. Systems theory has an established lineage, supported by the work of the organismic biologists, Gestalt Psychologists, and ecologists of the

1930s—and, more recently, the Cyberneticists in the 1950s. As Capra suggests, the "attention to patterns of organization, which was implicit in organismic biology and Gestalt Psychology, became the explicit focus of cybernetics" (p. 5).

Systems theory supports the idea that not all is chaos, as isolated studies of fractals and the butterfly effect might lead one to surmise. A system comes to exist because the agents involved settle into patterns that are routine and more or less predictable—they in effect *self-organize* based on how interdependencies are formed within and around them. Once a system has self-organized, the collectivity of agents develop characteristics that the individuals on their own do not possess. There is an *emergence* of qualities peculiar to that system that come about from the interconnections made by all the agents that make up the system. Waldrop (1992) provides an example of an emergent phenomenon:

> There's nothing very complicated about a water molecule: ... But now put a few zillion of those molecules together in the same pot. ... Those zillions of molecules have collectively acquired a property, liquidity, that none of them possesses alone. ... The liquidity is "emergent." (p. 82)

The emergence of qualities in groups is relevant to all systems, but particularly interesting to educators as it applies to social interaction and organization. No two classrooms will ever be the same because the teachers and students will all be different, as will the physical location and the parents involved. The changes become more complex as one moves out of the classroom to another or to a different school, or to a new school district, and so on.

Systems theory supports a biologically based view of the universe, which allows for phenomena to be framed in terms of living (evolving) processes rather than mechanistic (fixed) processes. The oversight of mechanistic thinkers is that they fail to see the importance of the pattern of a system. The linkages may seem invisible—particularly when seen through the biases of a modernist world view—but they are there, and it is out of them that the character and life of a system evolves (see Capra, 1996).

The phenomena of emergence is not strictly limited to biological systems. My thirty-five-year-old apartment building's hot water heating system, for example, needed a few components replaced this past year. Upon replacement of a pump, several owners began to notice and to complain about a new hum in the building. The heating system is in the basement, the complainants are on the second floor, and it is a concrete building. When the heating installation agent was called, he suggested that the problem lay in the fact that the pipes had developed a resonance with the old pump, and that they had not yet developed an "affinity" for the new one. He said the system was out of harmony—hence an incongruent sound running through the pipes. Apparently such disharmonies occur fairly frequently when sections of older, well-established systems are replaced. It was neither the pump nor the pipes, but what emerged from them together that had shifted.

Systems theorists of the 1960s were aware of emergent phenomena as indicated in the following section of a systems engineering text from the 1960s: "The systems engineer must also be capable of predicting the emergent properties of the system, those properties, that is, which are possessed by the system but not its parts" (quoted in Capra, p. 75). The systems theorists of the 1960s, though, were still led to believe that a thorough knowledge of the components of the system was all that was required for a complete knowledge of the system in operation. They believed that if they knew the properties of all of the parts they would be able to predict all outcomes. (This same mind set was/is evident in much more biologically-oriented fields, like medicine which, while changing rapidly, continues to consider the human body as a mere assemblage of parts, rather than a complex emergent system.) Recent research in the field of complexity (which arises, in part, from earlier work in systems theory) indicates that this may not actually be the case. As Capra, Waldrop, Varela, and others argue, what emerges often possesses unforeseen qualities that are in no way predictable—nor necessarily stable.

Systems theory, chaos theory, and fractal geometry all contribute to complexity theory's ability to make meaning of a planet where change is an integral component.

Closely aligned, but with somewhat different origins (in Continental philosophy, studies of perception, and Eastern thought), *enactivism* is another field of inquiry that is researching the patterns in and the processes that create life. The similarities of complexity theory and enactivism suggests that they may be radix of something that is as yet emerging from the postmodern sensibilities they both embody. One way or the other, they add to an understanding of each other. Each assists in moving academic discourse away from the dichotomous conundrums initiated by the views of Descartes and Newton—to mention a few: mind versus body, self versus other, knower versus knowledge, human versus nature, teacher versus student, classroom versus "real world".

Enactivism

Enactivism is the term used by researchers who are looking more specifically into the phenomenon of cognition. Taking the lead from Descartes' philosophy, the modernist world view is premised on the notion that the human mind is other than the world around it—that is, the mind is detached from its surroundings and, since it has no direct access to the "real world," it is faced with having to use the physical body's untrustworthy perceptions to create an "inner" model of the "outer reality." Because of the inevitable fallibility of the resulting world views, Cartesian philosophy also served as the impetus for the emergence of modern science—the doctrine, that is, that there is an objective way of looking at and learning about the world and that a rigorously empirical approach to research is the only valid way of forming knowledge.

A shortcoming of this approach is that it does not take into account that the mind cannot be separate from its environment: Rather than thinking of the mind as a distinct, self-contained entity, enactivism asserts that it is better to think of the mind as an emergent phenomenon. That is, the mind is neither contained in the brain, nor separate from the brain. Varela, Thompson, and Rosch (1991) develop this idea:

> His famous 'I think, I am' simply leaves untouched the nature of the 'I' that thinks. ... If Descartes had been fully rigorous, mindful, and attentive he would not have jumped to the conclusion that I am a thinking *thing* (res cogitans); rather he would have kept his attention on the very process of mind itself. (p. 62, emphasis in original)

Moreover, the mind is not strictly a subjective phenomenon. The thinking aspect of being human develops in conjunction with the other aspects of the systems in which the person is embedded. The mind is, in every way, influenced by what it is involved with. It is inseparable from its environment—we learn from those around us via our bodily (mental and physical) engagements with external and internal worlds. The hand, the foot, the tongue participate in the phenomenon that we call "mind"—and so there isn't a separation of mental and physical. Rather, "mind" is another order of phenomenon which is both biological and phenomenological—that is, the body is the thing that simultaneously separates us from (the body biologic) and places us in relationship to (the body politic) the rest of the world ... and that "dual embodiment" seems to have something to do with what we think thinking is. The body is that which allows the mind and the world around it to exchange experiences and information.

A biological zone like the coastal rain forest merges in a different way with the body/mind than that of a desert environment. Information isn't exchanged; rather, worlds are brought forth in the ever-new possibilities that arise in complex activity. Enactivism posits that the senses are not mere input devices. Rather, they participate in cognition. In fact, they are cognitive themselves, in a complexity theory sense. Perception and cognition are not separate phenomena. Cognition is therefore situational and dependent on the body's experience of itself and its environment (Abram, 1996; Capra, 1996; Davis, 1996; Varela et al., 1991).

That cognition is situational and dependent on the body's experience of self and environment has been made most apparent to me in my outdoor experiences. It is in the outdoors that I have become most aware of how my perceptions of the world are created from my interactions and my perceptions can profoundly shift when presented with a new environment to coemerge with. My perceptual shift when working as a ranger in the forest brought me to this realization. While I believed at that time that I still maintained an awareness of myself as distinguishable from the environment, with enough time alone in nature I am fairly sure I would begin to perceive quite differently than I do now. The crisp categories and labels I now apply to sky, tree, and animals would shift. As an example after one extended period in the forest I found myself calling animals "people"— like coyote "people". I came to think of them as kin to myself or perhaps had begun to view myself as kin to them — in some way coming to see similarities as opposed to differences in our way of being in the world. Being in and of the environment altered my experience and therefore my perceptions.

The harsh categorizing of everything I learned via my formal education and my cultural milieu always comes undone in my experiences out in nature. My parents owned a remote, log cabin far from electricity and urban amenities in the mountains of British Columbia when I was growing up. I recall being in deep winter snow there and experiencing a quiet so profound that I could actually *hear* silence. An oxymoron, yes —but still, the nature of the experience. After a time in that kind of quiet, the sound of the processes in my body and the forest became nearly indistinguishable. The whisper of unseen snow slipping off of a branch and the rhythm of blood pushing through my body melded and I was the sound of the forest. It is an amazing experience to not know if the sound you hear is your own blood moving in your body or the rhythm of the earth about you.

It is at these moments that my kinship to and one-ness with my world is made more apparent to me. In the same instant that I recognize myself as part of the world, I come to define myself as an agent with a certain autonomy or integrity within that world as the sight of the snow falling from a branch subtly reminds me that the event is occurring outside of the boundary I use to define "me": It is other than me. Some part of my sensing body—ears, eye, taste, touch describe and define, and I come to a conclusion about my relationship to the forest. It assists me to make distinctions. To define myself as a subsystem of this other system. Abram (1996) elaborates:

> The sensing body is not a programmed machine but an active and open form, continually improvising its relation to things and to the world. The body's actions and engagements are never wholly determinate since they must ceaselessly adjust themselves to a world and terrain that is itself continually shifting. (p. 49)

Enactivists, such as Varela, Thompson, and Rosch, point out that our cognition, our knowing, exists and consists through our actions in the environment:

> [T]he basis of cognition is not to be found in the Rationalist "I think'" nor in the Empiricist "I observe"—both of which are founded on the premise of the detached knower (or disembodied I/eye)—but in the enactivist "I act." Acting encompasses both thought and observation. (Davis, 1996, p. 11)

Even with my years of working and living in the forest, the intervening decade in an urban classroom has dulled my body and my mind's experiences of the natural world. When I return to forest settings, I am suddenly aware of my loss of knowing—made evident in my uncertainty on trails, in my diminished awareness of the wildlife sitting quietly, watching me visit their habitat from the edges of my campsite. My mind retains a trace of the time spent in the forest, but my body has been active within a building of square forms, of "super straight lines and right angles [that] make our animal senses wither even as they support the abstract intellect" (Abram, p. 64). The predators that worry me are not the cougars and the bears of a decade ago; now they are humanoid.

My actions in the forest this past summer, when contrasted to those of ten years ago, demonstrate a clear loss of knowing, while those in the urban classroom demonstrate a gain in knowing over that time. The situation or context in which I have been located has defined much of the learning and knowledge that my mind/body retains. Lave and Wenger

(1991) discuss the importance of considering the situation where learning occurs. In their inquiries into *situated learning*, they specifically focused on communities of learners, such as apprenticeships. However the concept of situated learning clearly has generalizable qualities, in that the situatedness of learning extends beyond human communities to global and biological ones. The point that situations are locations of learning has relevance to both my understanding of my life in the classroom and my previous work in the forest in that it assists in explaining the losses and gains of knowing.

Butterfly effects and their mathematical kin, *bifurcation points,* are points where critical shifts occur in a system. A "bifurcation point is a threshold of stability at which the dissipative structure may either break down or break through to one of several new states of order" (Capra, p. 191). They are junctures where the system forks or goes off into a new, perhaps similar but just as likely different pattern. Although the paths that a weather system or a human mind might take may be foreseeable in some limited way, it is impossible to predict them with certainty: The path the system takes will emerge within the context of its particular environment. Systems can be seen, then, to *co-emerge* or *co-evolve* as they react to and act with each other. Mind is a co-emergent process resulting from the body's engagement with its universe (Capra, 1996; Davis, 1996; Waldrop, 1992).

Even a simple action, such as wanting a snack, is actually complex and involves coemergence. In going to the refrigerator, I demonstrate a range of knowings that is, for the most part, unarticulated in the process of moving through the kitchen. That is, I am not particularly thinking that "I must walk to that point, I must then raise my arm to open the refrigerator, I must then pull, etc." Rather, I am feeling hunger and I associate the refrigerator with food and I go there—in the process demonstrating that I have knowledge that I attained from interactions with the environment in some way. The need to get that snack from the refrigerator is coemergent with many other factors. If all goes well, the body will get its desired nutrition but there is a great deal of action involved that is taken as a given yet demonstrated as knowledge in the fulfillment of the desire.

Enactivist researchers such as Humberto Maturana and Francisco Varela explain this in the sense that "to live is to know (living is effective action in existence as a living being)." (Davis, p. 193). The idea that the mind and body are separate is not applicable here. As living organisms people demonstrate their knowing in their actions.

Enactivism could be said to be coemergent with complexity theory, in that they are both involved in reconstructing theories in academic discourses. As a way of bringing this reconstruction into classroom curriculum, two fields have been of particular interest to me: Both fractal geometry and improvisational theatre offer ways of looking at and teaching that are in harmony with these postmodern sensibilities of change.

Curricular Links

Fractal Geometry

I was introduced to fractal geometry at Simon Fraser University in the summer of 1992 while taking a three-week math/computer course in Logo, a computer programming language. Prior to this course, I had little involvement with mathematics or computers and leaned toward literature and history as my strengths in teaching. Upon completing this one course, however, I became very interested in mathematics and computers—to the extent that the following year I took the position of teaching and managing the school's Macintosh computer lab as half of my teaching assignment. (The remainder of my assignment involved either teaching in the gifted program or teaching mathematics to the French immersion students.) The time was like a turning point in my own life where a new world view began to take hold.

While taking the course at Simon Fraser University, I became so immersed in the subject of fractals that I stayed up for several days at one point with just cat naps so I could complete a series of programs using Logo. I felt as though the mathematics involved in Logo programming had the potential to help me make sense of my world—something fell into place about mathematics being more than just a way of calculating. I told people at the time that I had been introduced to a new and eloquent language, and that a little-used part of my brain awoke and began to function—like stiff muscles being used. The experience created an expansion in my thinking and led me on to readings of chaos theory and, more recently, complexity theory and enactivism.

Theatre Sports

During the winter following the Logo course, I took a course in improvisational theatre through the Vancouver Theatre Sports League. Although seeming to be unrelated to chaos or systems theories, I ultimately discovered that improvisational theatre has more in common with these theories than one might think.

This form of acting is premised on the notion that the development of spontaneous action/thought is the route to our most creative, entertaining, and informative selves. Theatre sports encourages a minimalization of the editing and rule-forming habits of the mind. It gives sanction to act first and interpret later. The result of this kind of permission is that you come to trust your ability to safely introduce off-beat (and frequently great) ideas into a performance. The fear that some great irrevocable, trouble-causing mistake can be made is diminished. What is granted instead is a sense that there are many solutions to a problem, a sense that in groups we have endless resources among us to create wonderful outcomes, a sense that even though your ideas did not determine what happened, the mix or product contains was dependent on your input.

An awareness of the arbitrariness of many of our ideas and beliefs is generated in this manner of engagement. I have thus come to regard theatre sports as a sort of enactment of what the forest had taught me and what enactivist and of complexity theorists are looking into.

Teaching and Learning Complexly

With this simultaneous engagement of this pair of not-so-different discourses, I found myself in a new and exciting realm of thought, the implications of which I was already able to begin to explore in my teaching situations. I was hired to work in the school district's intermediate age gifted program, teaching several short and intensely focused units to students who were highly interested in particular subject areas. This resulted in my teaching a unit on theatre sports to drama students and a unit on fractals to math students. I also taught units on process (or sustained) writing to a group interested in writing for publishing. Eventually, I began to notice correlations among theatre sports, fractal geometry, and process writing. The three encompassed divergent, open-ended processes. In the cases of theatre sports and process writing, these fluid like processes were brought to bear on human activity and thinking; in the case of fractals, the focus was on complex phenomena such as weather and plant structures.

Each of the three units of study has an extemporal dimension, in that each allows the emergence of new thoughts and material to become the norm rather than the occasional occurrence. When I began readings in the theory of complexity several years later, I became aware of the fact that these teaching units that focused on divergence and diversity embodied many of the insights of complexity theory. I became intrigued about reworking the material and using it in intermediate grades, both as a subject of instruction and as a basis for rethinking processes of teaching and learning. I also felt it would be a starting place for exploring the development of a curriculum that addressed postmodern concerns.

It was with the original bit of experience in theatre sports, fractal geometry, and process writing, along with a glimpse into chaos theory, that I set out to design a curriculum which addressed the lack of attention to the insights of complexity theory. Along the way, I learned a great deal more about complexity theory and enactivism—but, more importantly, I was made aware of the potential of grade five students to embrace and work with abstract shifts in conception and perception.

Chapter 2
Designing a Complex Curriculum

Linear Versus Recursive Planning

The idea for this investigation into teaching arose from a structure that was initially sketchy—a loose-knit collection of possibilities that was based on preliminary understandings of my expected teaching assignment, my access to certain equipment, my experiences with improvisation and fractals, and numerous less conscious details (including my growing understandings of complexity and enactivism).

I began the study with the expectation that much of it would emerge along the way, and this proved to be the case. This expectation was linked to my pre-stated interest in extemporal opportunities—that is, to the conscious decision to stay open to and to explore those lively, transitive, and un-cause-able occasions that are sometimes called "pedagogical" or "teachable moments." This chapter is a recounting of the sort of thinking and preparation that underpinned the actual classroom engagement—told, of course in retrospect.

An important quality of the planning process (and of this retelling) is that the actual day-to-day events of the classroom folded into my thinking about what to do and when to do it. As such, the planning did not precede the teaching in a linear way, but emerged within the teaching in a more recursive manner—in a way that is analogous to iterative structure of a fractal image (i.e., where the output of one iteration becomes the input to the next, and so the actual nature of the result cannot be determined until the calculations are actually conducted). There are thus numerous references to classroom events, to learner personalities, and to other matters in this account of designing a curriculum.

Subsequent chapters, entitled "Enacting a Complex Curriculum" (Chapter 3) and "Interpreting a Complex Curriculum" (Chapter 4), focus more on what unfolded and on what it has come to mean to me as an educator.

The Activities

The class that I expected to work with was a group of twenty grade five French Immersion students, teaching their English Language Arts, mathematics, and computers. This accounted for forty percent of my teaching assignment. The remainder involved coordinating the school's computer lab and working with a variety of classes from around the school. Because I spent the largest portion of my time working with the French Immersion students, I decided to locate the research in that classroom.

My pre-teaching planning consisted of a web of activities that included generating fractal images (using the computer program, Logo), engaging in improvisational games from theatre sports and doing sustained writing practices—all with the intentions of enacting and exploring divergence and the manner in which difference arises from similar beginnings. The three categories of activity had the common strand of presenting students with the opportunity to learn in an environment where change was an integral part. As well, all three were intended to foster an awareness of how altering a part of a system can prompt it toward very different forms.

In an attempt to establish traces of unfolding events, thus demonstrating that we were not merely examining complex forms but that our lives were caught up in similar sorts of complex processes, both the students and myself were to keep journals of our thoughts during the year.

I was not sure about how to proceed until I actually met the students. One possibility I had considered was immersing ourselves in all three activities, simultaneously, for about three months. After getting to know the group, however, the curriculum emerged more as a progression. The path we took went first to writing, then to theatre, then into pattern and fractals. There was some overlap here and there, but it was fairly sequential.

We took about seven months (with several breaks), from mid-October into April, to conduct our explorations. For the most part, this came about because of the students' (and perhaps my own) readiness to work with the ideas and activities. They were keen, but they were young and not inclined to hurry their work. As well, we had to work on group dynamics from early on—to build some trust among classmates and teacher. Improvisation occurs when it is safe to take risks, so we had to establish that network first. Within the first two weeks of the school year, I found that I had to let go of many of my preconceived notions, some of which were derived from my recent work with the gifted classes. Due to the circumstances, I elected to begin with process writing, as it encourages divergent thinking, but in a manner that is more personal and that involves less public display.

Process Writing

Process writing is a technique used in sustained writing practice to get ideas past the trained editing function of the mind. It is designed to encourage lots of writing and the release of ideas without interference from concerns for grammar and spelling rules.

Process writing supports a dynamic system of thought where ideas move quickly and results are slightly unpredictable. I referred to the activity as "Five Minute Writing." To begin, students wrote sentences with a clearly defined character, action, and setting. (This was also supporting part of the grade five language arts requirements.) These three components were put on three different colors of tag board so that we could mix their sentence parts with everyone else's in the room and, from there, come up with starter ideas for writing. The starter sentence would be clipped up on the board and the students would begin writing non-stop for five to ten minutes using the sentence on the board as an idea generating point.

The idea was to not stop writing, regardless of where the plot was going and without concern for editing. What was important in this stage of the activity was not so much the structure of the writing, but the ideas generated and the length of the writing. For example, one student's scientific character got mixed up with another student's action of scuba diving, and with yet another student's setting of Disneyland. At the end of the writing session, students would read what they had written, either to the group or to partners. The following two story lines demonstrate how each student brought a story unique to their perceptions:

> There was once an oceanographer who's name was Bobby. He was making a trip to Disneyland. He wanted to study the lake near the water rides to see if any species lived there. When he got to the Los Angeles Airport he was covered in luggage (scuba-diving equipment). He stayed at the Disneyland hotel in Anaheim. Before he went discovering he has to think of a plan of how he can get in the water without any of the guards catching him. He told himself that he was going to dive with no splash when the guard isn't looking.
>
> The next morning he got up at 7 o'clock because he didn't want there to be a crowd when he went into the water. He took the Disneyland monorail to go to Disneyland ... [etc.]

Another student, starting with the same premise, wrote:

> Once upon a time there was an oceanographer named Bob. Bob took a week off to go to Disneyland. He lived in Toronto with this pet dog. He left the dog with his friend when he was at Disneyland. The first thing he had to do was buy a ticket. It cost him $699.00. He is going to fly in a plane called Canada 3000. He got there in two hours. The first thing Bob did was to buy a hot dog with every topping they

> had on top of it! Bob liked hot dogs very much because that was the first thing he ate when he was born.
>
> When Bob was born, he saw his Dad munching on a hot dog, so Bob started to cry. His Dad ripped off a little piece of hot dog and plopped it right into his mouth. Bob stopped crying. That is why Bob likes hot dogs so much. Bob finished his all dressed hot dog and decided to go on a roller coaster. When he got there was a very fat, lady sitting right beside him. Bob got squashed right to the edge of the coaster. Bob knew it wasn't going to be a comfortable ride right when he got squashed ... [etc.]

The two stories are similar, yet they are also quite clearly divergent. The same sorts of variations in character, plot, genre, and general content were evident across all of the writings.

When reading the students' stories, I worked from the premise that they would generate many ideas that would need to be edited when it was time to make a good copy. The freely associating mind seems to blurt out exactly what it isn't supposed to first—but once that is done, it seems to get beyond it and to generate increasingly innovative ideas. To truly get the innovative part of the process, the children needed the opportunity to get all ideas out without fear of reprisal. I thus strove to allow for "creative" license in these young authors by making minimal judgments on content in my initial responses.

There were some matters that I commented on. I explained, for example, about "gratuitous" humor being too easy—that is, that bathroom and body part jokes were funny just because we are not supposed to discuss these topics. I made requests to stay away from gratuitous humor, if possible, and not to use classmates' names.

We continued with sustained writing practices for about a month before we wrote complete stories. By this point we had begun theatre sports, which dove-tailed well with the writing. The information we had learned about plot, setting, and character, and the exploration of divergent writing, created a firm link into the more animated field of theatre sports.

Theatre Sports

Theatre sports, in its complete form, is a kind of drama where the actors improvise based on input from the audience. They are given a location, an activity that will take place, and some quality that the key characters possess, all of which they are to incorporate into a short skit. They are "judged" by the audience on their ability to develop a cohesive plot with a clear beginning, middle, and end. Not all theatre sports activities create skits; much of it is based on short games done with partners or alone. In every case, however, there is some form of requirement that pushes for divergent thinking and action. All games have to do with letting go of an idea and picking another one—quickly. These are powerful improvisational games. Like process writing, they are designed to free up our states of locked-in thought editing and to assist access to the creative aspects of the mind.

Take for example the game, *Never Mind That.* Students, working with partners, begin with one making a request of the other—something simple, like, "Tell me about the color yellow." The partner starts out by making up a story about the color yellow, but as soon as something interesting is said—like, for example, "The little yellow dog was running down the street with a hot dog"—the partner interrupts and says, "Never mind that, tell me about the hot dog." And so the partner prompts a divergence in the story, which continues with the new focus on hot dogs (or whatever), only to be interrupted in the same way within a minute or two. What this is intended to do is to compel the mind to let go of whatever idea it selected as its object of focus and incorporate a new line of thinking. This game engages the students in quick, creative, unedited thinking.

In terms of the imagery of fractal geometry, *Never Mind That* creates a series of bifurcation points in a story line, which serves to increase potential directions of the tale. One partner selects the location of the bifurcation point and the direction of change while the other partner, the story teller, accepts these influences and takes the story somewhere new and unexpected. Theatre sports might be seen in terms of an elaboration or enactment of this sort of participatory or coemergent story-making, and it is precisely the resultant unpredictability and uncontrollability that creates the tension, humor, and innovation that the activity is noted for.

Another theatre sports activity is the game, *Die*. Students stand in front of the class in groups of four and begin a skit based on an assigned location, setting, and conflict—all of which are suggested by the audience. As with other theatre sports, it is the actors' task to build a plot line that incorporates all the critical aspects of a story—but, in this case, each actor is permitted to speak for only a sentence or two. When the director points to a team member, they must pick up the story line and continue with it, keeping in mind what came before from the other members. That person talks until the director points to another team member. If the actor loses the train of thought, takes too long to start talking, or repeats what the last person said, the audience yells, "Die!," and that person has to sit down. The last person standing is the winner.

Die is like the *Never Mind Game* in that it forces quick thinking, but it is more challenging in that it requires paying a particular attention to what has gone on before. It can also act as a location for learning about personal attachment or investment in particular ideas, because your own idea of where the story is going is constantly being interrupted by the larger group's input. The story creation in *Die* is like other theatre sports games in that it sets up a process where ideas are coemerging or coevolving with the other players' contributions. The more players (or agents), the more complex the story "system" becomes.

There is an escalation in complexity from *Never Mind That* to *Die*, in that it becomes far less to possible be controlling in the latter. In *Die* the players can no longer control the story line when interrupted because there are usually two or three people adding to it before it completes a cycle back to them. If a player attempts to control the flow of the story, it is called "blocking" or "whimping," and the referee can call them for it. They are allowed to contribute but are unable to exactly control it — just like existence in most living systems.

Complexity increases even more in other games. The game *Strips*, for example, involves additions of extra dialogue to story lines that arrive from outside of that generated by the actors. This is accomplished by placing strips of paper, each with a brief quote, face down on the stage. Every so often during the play, an actor must pick one of these up, read it aloud, and then the team must work it into the story line (which they are acting out, and not just telling) along with whatever their fellow actors are contributing. Within this sort of process, a tomato has the potential to become a revered pet or a dreaded bomb. The point in the theatre is to increase both the challenge and the absurd humor factor. The ways that the actors strive to hold the system together while struggling with the diverging forces of the players and the limitations of the game make these activities excellent locations for looking at the insights and the interests of complexity theory. A good example of this is found by looking at the theory of dissipative structures.

Physicist Ilya Prigogine studied instability in systems and researched how organisms self-organize in conditions of nonequilibrium (Capra, p. 86). This led to his theory of *dissipative structures*—a theory that addressed the observations that systems are held together by some form of attraction. In dissipative structures there is an attraction to order. This phenomena is also known as the "strange attractor," and it is a notion that is critical to self-organization (which, in turn, makes it an important idea in complexity theory and enactivism). Capra explains:

> When a dissipative structure reaches such a point of instability, called a *bifurcation point*, an element of *indeterminacy* enters into the theory. At the bifurcation point the system's behavior is inherently *unpredictable.* In particular, new structure of higher *order* and complexity may emerge spontaneously. Thus self-organization, the spontaneous emergence of order, results from the combined effects of non-

> equilibrium, irreversibility, feedback loops and instability. (p 192, emphasis in original)

Given these concerns for indeterminacy, unpredictability, feedback loops, and bifurcation points, it is clear that theatre sports games might be characterized as enactments of dissipative structures. In terms of a complex system, these games involve the actors in a system that has been proscribed in a particular way (i.e., by the stated rules). These are imposed by the referee, who also becomes a participant in the system, and are further constrained by the initial conditions set by the audience. The result is a self-organized system in which the players must act according to the defined parameters for appropriate activity. Within these assigned parameters, the strange attractor is the desire to build the plot and adhere to the rules of the game.

Continuous novelty and unpredictability are ensured through the strips of paper on the floor. The individual ideas of the different players are also contributing to randomness in the system, thereby creating non-equilibrium, feedback loops, instability, and irreversibility. This means that the actors must constantly work to adapt to their changing environment—so the level of complexity is always on the increase. It is very much an enactment of a chaotic system, always on the edge of bifurcation, yet still attracted to the original order. The requirements made at the start—the initial conditions—set the system in its structure which it then seeks to maintain. The theatre sports games thus represent ideal ways of enacting very complicated concepts from science and cognitive psychology within what I would consider to be an extemporal classroom climate. Extemporal teaching does not mean a rejection of deliberately structuring and ordering learning experiences. Rather, it means a rejection of the notion that such activities will somehow determine or control the learning that happens. In rejecting this, the teacher must still plan—it's just that the planning, like each successive iteration in a fractal image, depends on the outcome of the previous iteration. This is truly laying down a path in walking. Theater sports and

Improvisations are excellent ways to begin working extemporally but it is applicable to all learning situations.

The next lesson overlapped with the theatre sports, sharing many of the qualities just described. Having sprung to mind while I was listening to a radio show on the way to university after school one day, the idea came to fit in with my activities as an educator in much the same way that the strips of paper or the unanticipated audience input fits into various theatre sports games.

The Stone Game

While driving one day, I heard Dr. Joseph Schaeffer, a guest on CBC-Radio discussing an activity that he called the *Stone Game*. In the interview he described a strategy that involves playing with rocks which he uses to help people toward understandings of how systems develop. He has used it to assist members of the Royal Canadian Mounted Police in addressing the tension between turban-wearing officers and those in the police force who are uncomfortable with the recent policy allowing alternative headgear. His description of the process sounded so akin to what I was doing with the children that I decided to break from Theatre Sports and to try some literal "hands on" activities with rocks—a bifurcation point in my own curricular planning.

In brief, the game involves creating an image or design with stones (Figure 4). The rules of the Stone Game, as I recalled them and as I was later to assign them to my students, are as follows: First, players can only put down one stone at a time. Second, they are permitted to talk about anything except what they think they are building. Third, players are not allowed to direct another player's choice of where a stone goes.

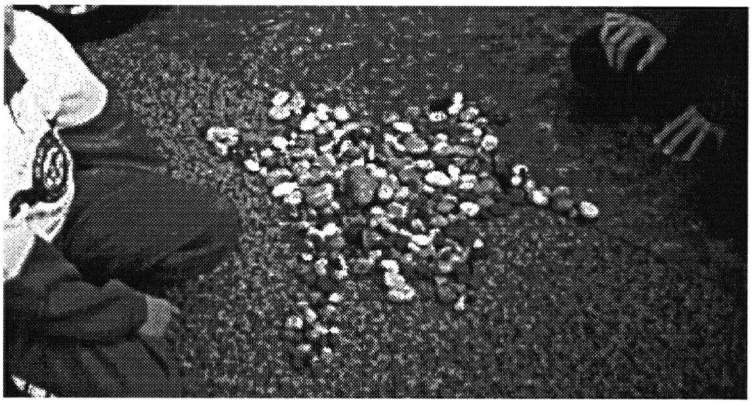

Figure 4: Stone Game Pattern

I went out to a beach that I have frequented since I was a child and collected a lot of smooth, round beach stones for the game. It was raining while I collected the rocks. The beach was void of people. It was windy and, by the time I left, the rocks felt very special to me. I felt there was an important *knowing* in the rocks' connection to that ocean shore and, hence, to the planetary system. I felt a returning to something more essential to myself; something that I am less able to articulate. Perhaps it is best described by the phenomenological notion of returning to the primal experiences of life:

> The famous phenomenological dictum "back to the things themselves" suggests a "preconceptual" realm in which experience is yet to be articulated. ... This phenomenology is said to call us back to "lived experiences," those spheres of time, space, and experience that ontologically antedate all conceptualization. (Pinar, 1992, p. 4)

In retrospect, I think I was struggling with a desire to pass along my lived experience to the students. Even though it is an impossibility to transfer my knowing to the students, it is still a part of my being as a teacher to want to share my experiences with them in some way. I am deeply inspired by the natural world and I wanted to impart some of my own learning about that—something beyond the theoretical to the students. My puzzling over how to bring this connection back to the classroom was represented by my four cardboard boxes of wet stones. At this point even the enactment of theatre sports seemed to miss the lived experience available on a windy beach. Ted Aoki (1988) appreciatively references Merleau-Ponty when discussing this gap between knowing theory versus experiencing the world it seeks to explain:

> The whole universe of science is built upon the world as directly experienced and if you want to subject science to rigorous study ... we must begin by reawakening the basic experience of the world of which science is the second order experience. (p. 404)

Short of being able to provide the students with access to the beach, I settled for four boxes of wet stones, complete with sea weed, and hoped the experience of handling and using them would in some way leave them with a trace of the rocks' connection to the earth—and hence to themselves.

To begin the game, I simply put the stones out on the floor, divided the children into groups, each with a pile, and explained the rough game plan. We spent three classes on the Stone Game, culminating in a discussion of how patterns and symbols form in collective exercises. Students also took part in assessing what each other's patterns looked like to them and categorizing them. (See Table 1 in Chapter 3.) A class discussion followed on how, at times, their ideas varied from each other and yet, at other times, how they were similar.

Fractal Geometry

Fractal geometry was a component of my planning from the beginning, but the ways that it emerged in the curriculum and the manner in which it came to link with the foregoing differed from what I had initially envisioned. I had originally anticipated using the computer language, Logo, in the making of fractal trees—just as I had done at Simon Fraser University in my training. What emerged was a broader study that linked the enacted aspects of the process writing, theatre sports, and Stone Game activities to the slightly more abstract explorations of the mathematical concepts of fractal geometry. As it turned out, the first part of the inquiry did not involve the computer at all, arising instead from a book (*Fractal Cuts* by Diego Uribe) that I had bought in London, England on a holiday.

Paper Models

I had purchased *Fractal Cuts* a year or more earlier, but I hadn't found time to read it and I wasn't sure it was even relevant. In the autumn, however, I noticed that a colleague at the university had some of the completed paper cuts in his office. He had used them in some capacity with his students, which prompted my interest in using them with mine (a little coemergent phenomena in itself). After developing some mastery of the cutting and folding activity, I used them to introduce the section on fractals.

I began the activity by giving students a sheet of paper and directing them, step-by-step, through the cuts and folds involved in constructing pop up paper models of simple fractals. The paper cuts made for a great hands-on introduction to the notion of fractals and, in particular, the concept of self-similarity. The first paper cut that we worked through (shown in Figure 5), for example, illustrates self-similarity in the way that smaller rectangular shapes come to be embedded in larger, similarly shaped rectangles.

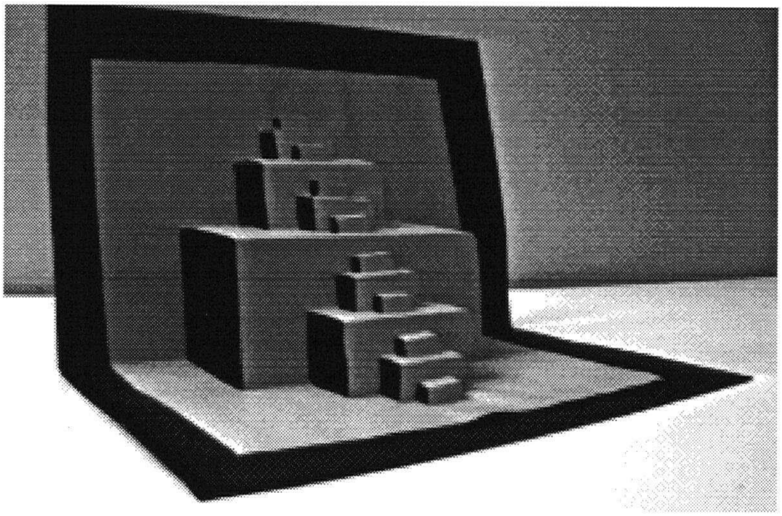

Figure 5: Central Quartile

In some ways, these models span two fields of geometry (i.e., both Euclidean and fractal) as they have clearly defined geometric shapes, like rectangles, squares, and triangles, while demonstrating self-similarity, recursion, and other notions from fractal geometry. Further, the cards can be used to address the idea that the natural world appears to be made up of many interconnecting shapes that look a great deal like each other.

After a week and a half of cutting fractals, we moved out doors to locate fractal-type matter around the school yard. This idea came up one day in later winter when it stopped raining for a while, allowing us to go outside to look for forms that had fractal-like structures. This respite occurred at a moment in the lesson when the students had demonstrated to me that they had grasped how to apply the concept of self-similarity to the world around them. It made sense, in that moment, to head out of the class into a closer connection with nature to see how the theory applied to the matter around us.

Connection with Nature's Fractals

As a class, we went outside to collect samples that demonstrated self-similarity. I reminded them not to denude the shrubbery around the school and to take only small, meaningful samples.

For an hour and a half, students sought and located interesting bits of nature, showing the others in the group what they had located, and describing the components that demonstrated self-similarity. They organized themselves with very little input from me, doing "Show and Tell" to explain what was reflective of fractal geometry and self-similarity in their personal samples.

Back in the class, we mounted the samples on presentation board and then posted these on the wall as a display. During this section of the study, we had a discussion of the term "butterfly effect" and of the roles played by Edward Lorenz and Benoit Mandelbrot in the emergence of the field of fractal geometry. We talked about storms and butterflies flapping their wings and the possibilities of the influence of one action on a larger system. The conversation actually came up in the context of a discussion about the self-similarity of clouds, which led to the topic of weather systems and then to Edward Lorenz.

Before beginning with the Logo section, I wanted to confirm my impression that all the students had developed appreciations of the ideas of self-similarity and fractals. A few classes later I asked them each to find a picture of something that demonstrated fractal geometry and to include a written explanation of why it was a fractal. Each student found a reasonable sample and wrote sensible explanations. (See Figures 13 and 14, in the next chapter, for some examples.)

Logo Programming

Extemporal Variables in Class Dynamics

For one hour each week, we had access to the computer lab to explore the program, Logo. Logo uses a combination of words and numbers to instruct the computer to draw something. The input is algebraic, but the outcome is geometric.

I began with the simple task of teaching the students how to draw a square. From there, I intended to move on to adjusting the square-drawing program so that a star would be constructed.

The program we began with was: Repeat 4[Fd 80 Rt 90]. This directs the computer to move forward 80 pixels and turn right 90 degrees, and to repeat this action 4 times to create a square. I wrote the program on the board and explained what it was directing the computer to do. I then pointed out that the computer could not understand words that were not spelled correctly, nor spaces in the wrong places. I then left the students to draw the square—which they did, moving on to discover how to draw circles on their own. (See Figure 15. I elaborate on these events in Chapter 3, "Enacting a Complex Curriculum.")

Square Stars

The following week I showed the students how to write a program so the computer would draw the Square when the word "Square" was typed in (rather than having to type in the complete list of commands each time a square was to be drawn). They used this knowledge to use the Square program in making a star-like circle (Figure 16).

Following these initial exercises, I had students spend a class working on concepts and skills they would need for the next section (which involved manipulating variables in a formula to create fractal trees). They worked for one class period making the Logo turtle zig zag and draw arrow designs with a view toward developing some facility with the angle (turn) and pixel (distance) commands that are basic to writing fractal formulas. They also learned and applied the skill of reading angles up to 360°.

Key to fractals is a process called "recursion." It is like the process that creates self-similarity and it is based on iterative functions in mathematics. Basically, a recursive procedure is one that, in being enacted, directs the computer to enact it again, which leads to the request to enact it again, and so on. A process is then set up that has the potential to be infinite. It is like the effect of standing between parallel mirrors, seeing not just a reflection of yourself, but a reflection of a reflection, a reflection of a reflection of a reflection, and so on.

With the fractal cuts, the effect of a recursive process is evident in the way that the rectangles are all smaller versions of the one produced with the first cut. The computer fractal may call upon itself to draw itself in exactly the same manner each time, or to graft an image that is a size smaller or larger onto the emerging figure (as is the case with the fractal cuts). These recursive commands, combined with very small changes in variables, are where one finds the correlation between fractals and the systems of the world:

> Many of the mathematical fractals that can be generated out of a single, repeated iteration have a wealth of detail, yet they're far too orderly to correspond to natural forms. ... However, when a random variation in the iterations is allowed so that

> details vary from scale to scale, it's possible to mimic the actual forms and structures of nature much more closely. (Briggs & Peat, 1989, p. 104)

In our study of Logo, we did not get as far as random iteration commands, but we did get to a point of manually applying the concept. So the students attained a sense of how random factors might cause all the wonderful variations of similar themes and forms that we find around us.

Reading Formula: A Move from Graphic to Abstract

To introduce this section to my students, I wrote Program 1 (a simple formula for making a star—see below) on the board, and the students typed it into Logo. This was a different star than the one that was made using the "Square" command in the earlier class. The important difference between the two stars was that this one was as a star from the beginning, as opposed to being a collection of squares that came together or emerged into a star.

Program 1

```
To Star 1
Repeat 5[Fd 60 Rt 144]
End
```

Program 1 is *not* recursive. It draws a short line and then turns sharply (indicated by what is inside the brackets) five times, and then stops. I explained this to the students after they entered it into their computers.

I then had them type in Program 2, which *is* recursive but will not terminate. It keeps telling itself to draw itself. After initiating this program, students had to use the computer's "Stop" command to force an end to the drawing—and the need for this action brought home the fact that Program 2 would go on forever if something from outside the program didn't interfere with it to force it a quit.

Program 2

```
To Star
Fd 60
Rt 144
Star
End
```

We ran out of time in the computer lab, and the next class was one week away. Thinking that we would be able to work through two new programs by using the instructions to hand-draw the figures, I wrote Program 3 and Program 4 on the classroom blackboard the next morning.

Program 3

```
To Star :L
Fd :L
Rt 150
Star (:L-10)
End
```

Program 4

```
To Star :L
If :L<0 Then Stop
Fd :L
Rt 150
Star (:L-10)
End
```

My intention was to have students take turns coming up to the blackboard, each "drawing a command" as it was read from the program. As it turned out, and to my surprise, several class members were able to explain, quite clearly, what was going on—leading me to realize that they had learned to read the computer programming language quite well. (I elaborate on this matter in the next chapter.) For the benefit of those students who had not yet developed this ability, we did as I had planned and drew the three images. In the drawings, what became apparent to all was that both Program 3 and Program 4 contain the instructions to draw a star whose sides gets smaller and smaller (as 10 pixels are subtracted from the length of the segments with each round). The difference between the programs was that <u>Program 4</u> had a stop mechanism written into it to stop when the variable L was less than 0.

Programming Tree Shapes

The final Logo task was to experiment with different variables, done in the context of drawing a rendition of a tree. I provided the basic fractal formula for a tree drawing (Figure 6).

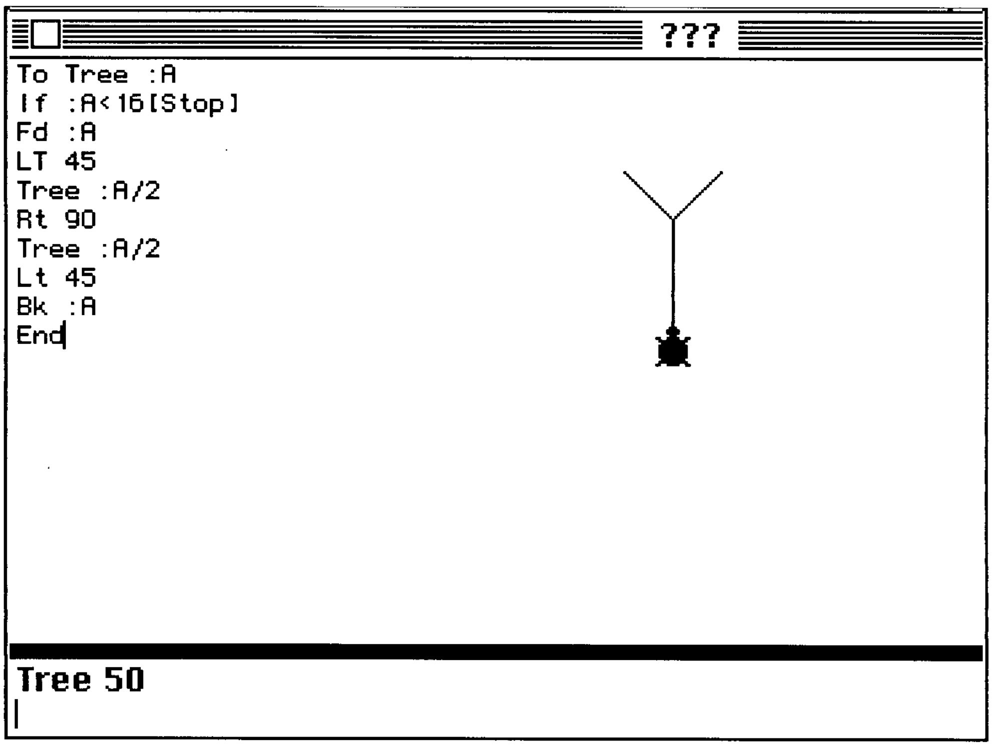

Figure 6: Drawing a Fractal Tree in Logo

Working from this initial formula, the students were to experiment with methods of making the resultant image look less like a stick and more like a tree. The students made various kinds of trees—some more elaborate than others—but they all demonstrated an ability to manipulate variables in a way to approximate tree growth. Further, they all demonstrated an appreciation of the fact that changing something incrementally can have unexpected and dramatic effects. In fact some of their formulas became so odd that the resultant images didn't resemble trees at all.

We concluded the fractal section by looking at the "Mandelbrot Set" (a particular fractal image, named in honor of fractal geometry pioneer, Benoit Mandelbrot), using a computer software program that came with the book *Fractals for the Macintosh.* (See Figures 1, 2, & 3.) This program generates big and colorful fractals from the Mandelbrot Set, along with the formulas for the parts of the fractal that has been generated. That is, each image that the program generates is actually a fragment of the Mandelbrot Set. The program specifies which part, in algebraic terms.

While the mathematics was far beyond what the students could read, they were able to see the correlations between the formula they had just written in Logo and the ones used in this more advanced version. The Mandelbrot Fractal Program offered an opportunity to link what we were doing with post-secondary research—a link to the adult world they long to be included in.

We also further discussed the "butterfly effect" and watched both Benoit Mandelbrot and Edward Lorenz, two key founders of the field of fractal geometry, on a pair of videos (*Focus on Fractals,* 1992; *Fractals: An Animated Discussion*, 1989). These videos had been prepared for an adult audience so, I edited them before using them in class. The children got to hear both researchers talk about the field, describe their contributions and mention how they felt it was contributing to scientific research.

Introducing "Complexity"

To integrate the entire journey from October to April, we engaged in a group brainstorming and web making activity one afternoon (Figure 7). I took this opportunity to explain that all of what we had done could be gathered together under the umbrella of complexity theory, and we branched off from there.

We reviewed what we had been involved in and put down thoughts they had about any of the sections. I talked about Newton's view of the world as a mechanistic device and contrasted it with Mandelbrot's image of the fractal. We got into some discussion around Mandelbrot's example of the coastline of Britain—that is, the notion that a coastline should be seen as being comprised of increasing folds so that every time you magnify a section for re-examination, you see it has more folds (out of which a question of the possibility of measurement arises). We thought about how to describe a cloud with its maze of self-similar yet moving shapes, along with the inadequacies of traditional geometry for dealing with such forms.

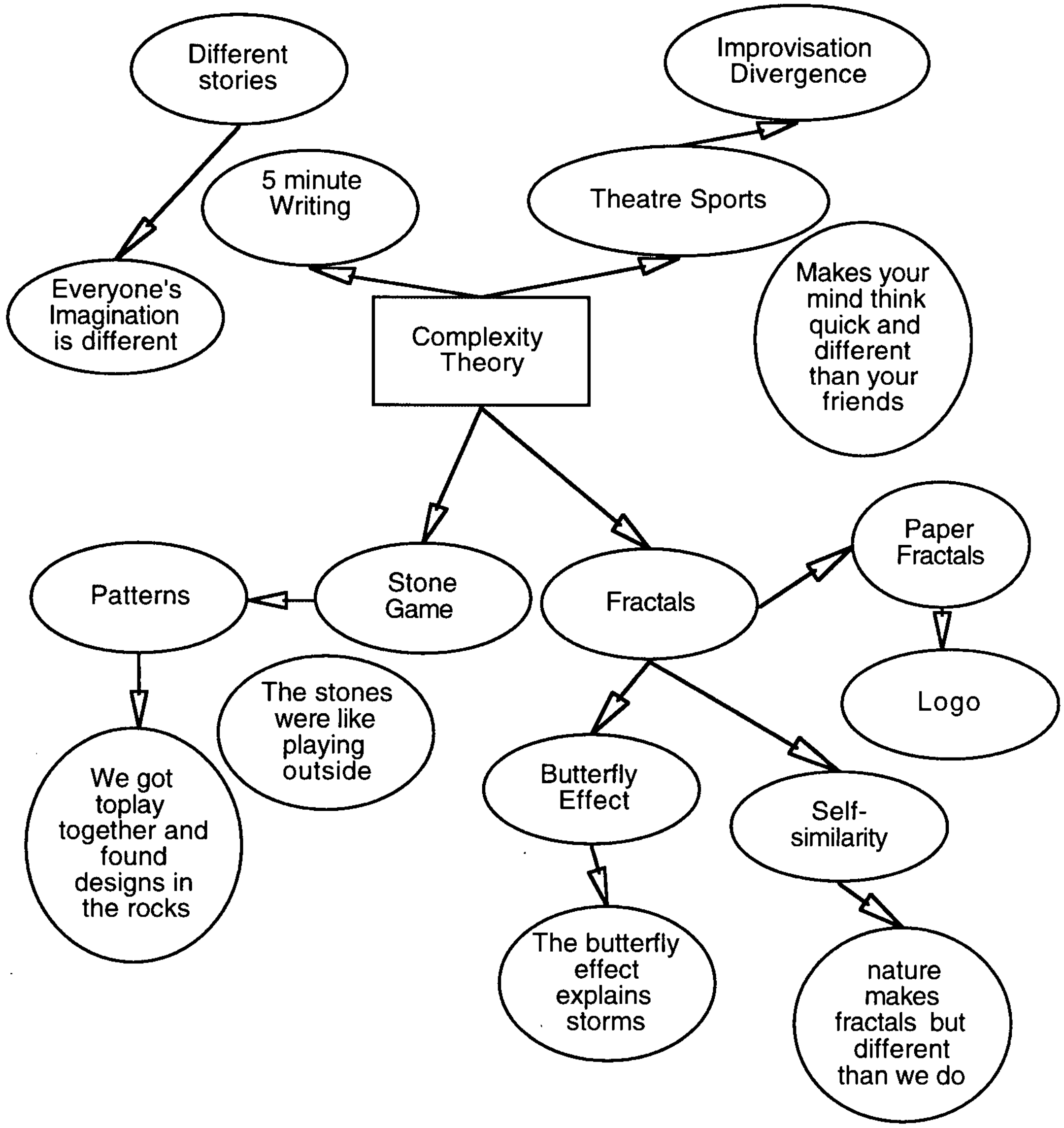

Figure 7: Section of Brainstorm

The brainstorming was followed by personal journal entries about what they had found most interesting in the year's study of complexity. I wanted to see how much of what we had been doing had merged with their way of being in the world—what were they getting from it. Their journal writing had improved consistently over the term and was proving to be a great source for my making sense of what they were gleaning from it. I did not ask them directly what they thought they had learned, instead I asked them to comment on their thoughts about the different activities we had engaged in and what their thoughts were about them. I didn't want to "lead" them to conclusions. I was wanting to see what they might have come to on their own over the months.

I was not being overly directive. Over the previous months I had them engage in some novel experiences that involved looking at models of change in systems, supplied some training for basic skills of analysis and response to them (improved language arts and math skills), and was wanting to see what they had come to from this. I was not particularly expecting, in any way, to be able to produce immediate, quantifiable results. There was no "test" with terminology on it—asking learners, for example, to define "divergent" or "improvisation" (although using those words correctly in context had been part of the spelling for several weeks). My desire was that much of what we were engaged in would apply itself in their lives. While enacting the above "plan" and watching and reading their responses to the activities, I came to believe that they had attained a new degree of "Knowing."

Chapter 3
Enacting a Complex Curriculum

Natural Drift and Enaction as Knowing

To understand the enacting of a curriculum that is based in complexity theory, it is important to give thought to what knowing is. With many other educators, I question that conception of knowledge that sees learning as a process of accumulating a list of reductionist facts as. A curriculum bound by rigid lesson plans, outcome statements, and criterion-based assessment does not allow much of the student's own experience to emerge. Madeleine Grumet (1995) uses the analogy of traveling to further explain the difference between education as a process of developing knowing (versus a static, fact-collection procedure): "[E]ducation is about a human being making sense of her life in the world, and when we confuse her movement with the stops on her itinerary, or worse with someone else's travel memoirs, we obstruct it" (p. 3).

On the other hand, what is encouraged to emerge in an enactive process is the students' own understandings, which are demonstrated by their actions in the emerging classroom dynamic—a dynamic that is always shifting to some degree. In an extemporal climate—where mindfulness, improvisation, divergence, and experimentation are key ingredients—the students are encouraged to be active agents in the dynamic choreography of knowledge rather than passive recipients of data. In this way the students involved in this study demonstrated they had attained a "knowing" about complexity theory. They began to incorporate the language into their written and oral descriptions of their experiences (as indicated by the quotes in the following sections). It was in their explanations and discussions about their observations and experiences of the world that I noticed that aspects of complexity theory had made its way into their awareness and had become a part of their knowing.

For myself, teaching and learning are clearly not about the act of students memorizing parts and regurgitating them on demand. This is not to say that, as the teacher, I do not seek to develop certain skills or degrees of accountability in my students. I expect their practical skills to improve throughout our tenure together. However, the greater knowing is in an ability to make intelligent choices throughout life's changing conditions—as opposed to mustering defenses to sustain one's perceptions of reality. Educational researchers Davis and Sumara (1996), citing Pirie, have referred to this teaching/learning environment as one of "liberating constraints" which are intended "to strike a balance between 'complete freedom' (which would seem to negate the need for schools in the first place) and no freedom at all" (Davis, 1996, p. 97).

Hermeneutic sensibilities shed some understanding on my notion about bringing an extemporal quality to teaching and learning in the classroom. It is about encouraging a way of living, throughout life's ups and downs, that does not seek to create and maintain a false sense of control (along with its subsequent disappointments). As Jardine (1992) explains,

> [H]ermeneutic inquiry has as its goal to educe understanding, to bring forth the presuppositions in which we already live. Its task, therefore, is not to methodically achieve a relationship to some matter and to secure understanding in such a method. Rather, its task is to recollect the contours and textures of the life we are already living. (p. 116)

In attempting to enact this hermeneutic sensibility in my own teaching, I am seeking to have students reference the occurrences and events that are relevant and related to them in the contexts they are in. They may then do what they will with this learning as their lives unfold in their own unique manners. It has to do with the situation in the moment—not without regard for the future, but with a willingness to let go and accept what occurs in the next moment without holding out for it to meet our expectations. Extemporality has a similar quality: a sense of allowing the learning to emerge from the context of the subject matter, the students' contributions, and all the other less obvious parts of the classroom system in operation in a given day. Less control; more *extempore*.

Within the public education system of North America, "knowledge" seems to have become synonymous with training for jobs—an attempt to guarantee a future that is as yet unknown. While this is often one desired outcome of educators—that they will assist the child in finding meaningful employment as adults—it falls short of what might really be needed to find meaning in life. Knowledge has been seen differently in other eras. Madeleine Grumet and William Pinar (1988) point to the Socratic era as one example of what has been let go of in American curriculum and what it has been replaced with via the modern era.

> Gone is the Greek insight that theory is the cultivation of wisdom ... that contemplation is essential to the cultivation of wisdom. ... Present is the demand for knowledge of circumstances not yet present, for theory which attempts to control the future as it anticipates it. (p. 92)

Pinar and Grumet do not see the Socratic era as any sort of perfect time, but they recognize the loss in our own era of the space to question the ground of our actions. The teacher, the curriculum policy makers, the school climate fill all available educational space with the designated curriculum model of the day—a model hoping to predict an unknown future and its needed skills. It all too frequently leaves no room for the development of the student's own acting (which is, in enactivist terms, an enacting of one's knowledge: knowing).

Another way to look at extemporal teaching/learning in education is through Varela, Thompson, and Rosch's (1991) discussions of *natural drift* and enactivism. Natural drift is a rethinking of the Darwinian theory of *natural selection*. Natural drift posits that adequacy or "survival of the fit" is actually the preferred mode of survival in the lived world, not optimality or "survival of the fittest."

> The first step is to switch from ... the idea that what is not allowed is forbidden to the idea that what is not forbidden is allowed... in a modified sense: selection

> discards what is not compatible with survival and reproduction. (Varela et al., p. 195)

The educator's role may be to assist the student in accessing a diversity of paths compatible with their own awareness of what does and what does not fit with who they think they are. Developing the ability to question the ground of our actions—that is, to avoid an unthinking pursuit of doctrine or uncritical common sense—is a necessary skill in the milieu of changing conditions that defines living systems. This capacity to reflect on the situation at hand is an important skill that has been pushed aside in our outcomes-based, criterion-referenced, and future-oriented curricula. The abilities needed to adapt in the complex and shifting circumstances of the immediate moment are quite different than the narrow band of abilities needed to succeed on formal exam papers. Appropriate knowing emerges from the collectivity of the moment. It is embodied in a person's actions.

As I see it, it is my job as a teacher to assist learners, not to dominate them. They have much information already—even at six years old students have an amazing array of knowledge. As an extemporal teacher, I seek to provide the conditions through which learners might develop a certain level of concrete skill, but ultimately I want to encourage a classroom system that allows each student to bring forth and demonstrate their embodied (but not necessarily explicit or formulated knowings) knowings and capabilities. My own role is that of an advisor, perhaps a co-inquirer, participating with students in the ongoing evolutionary drift of their learning.

I want my students to learn a way of being that is founded on a greater awareness of interdependencies and co-evolutions—and to use that awareness to strengthen their adaptability to and trust in their places in the larger system they exist in. An approach to teaching that seeks to dominate them and to fill them up with data (that is, with "knowledge" that is conceived as something external, inert, and transferable)—or worse, that discards them from the system when they do not fulfill the predetermined requirements—allows them to know neither themselves nor their world. I see it as my job to assist learners in developing their capacities as capable interpreters of their ever–shifting circumstances so they might take the path appropriate for themselves in every moment.

It was with this sense of what "knowing" is that I noted their responses to the lessons in complexity theory. I sought to make some sense of shifts in perception that the students might have experienced with regard to themselves and/or their world. This was far more important to me than a memorized Logo formula or appropriate usage of the language of complexity theory. The following are a sampling of the students' and my responses to what was outlined in the previous chapter, Designing a Complex Curriculum.

"Results"

Process Writing

When we began the 5–Minute Writing exercises, many of the students could only write a very short paragraph. By the third class, however, they were writing three and four pages in ten minutes and developing sophisticated characters of their own. Those who had difficulty with spelling also demonstrated themselves capable of producing interesting plots—once they were given the opportunity to decode their personal phonetics.

Students were silent, on task, and excited about the daily task of writing. They seemed to thrive on the permission to express their own individual stories. They quickly demonstrated in their engagement and in their written products that they did know how to write—and that, given the opportunity to edit later, they had many interesting ideas to express and share.

In discussions about writing this way, the students commented on how different their stories were from one another—given that they had all begun from the same sentence. I had dictated the genre and pre-specified the basic setting, so they were truly surprised to see how varied they all were in their ideas. This provided an opportunity in context to work through the concept of divergence—a basic principal of chaos dynamics and complex systems —with them. We talked about how everyone brought their own ideas and experiences to their stories and how those differing backgrounds contributed to the noted divergences.

Although my explicit intention was with laying the foundation for this critical principal of complexity theory—that is, the role of changing variables (in this case each student's personal ideas) in a system or process—the students were also learning their "basic" skills: In the context of this study of writing, I taught about character, plot, setting and genre. Students were engaged in generating longer written passages, in oral reading, in developing their editing skills. The activity prompted an increase in creativity in the class and contributed to a growing sense of trust. Students were required to use the words that came up (such as "divergent") in context and in complete sentences:

> "The car diverged off the side road onto the freeway."
>
> "The gay boy diverged from the other boys as a teenager."

Their definitions were as varied as their writing had been. I could have diverged or bifurcated off into some very interesting class discussions just based on their definitions, but decided that as long as I thought they had the gist of the term, I'd leave them to further the definition as it came into use in their own way.

While I had a general plan in place—and occasionally pressed home a grammatical point to a student—I preferred to leave space for the learning that was emergent and in context. Davis, Sumara, and Kieren (1996) discuss how, in the context of their teaching, one cannot control learning outcomes, since so much of the learning situation co–evolves in the context of working with these students in <u>this</u> class at <u>this</u> time and I found the same to be true:

> Consistent with the conclusions of researchers working with chaos (Gleick, 1988) and complexity (Waldrop, 1992) theories, and as supported by the student's actions during the *Missing Fraction Mystery,* we argue that we cannot hope to predetermine

> the consequences of any particular teaching or curricular act. Like any social event, learning is a complex phenomenon; it resists linear and causal reductions. (p. 77)

Each student was learning similarly, yet each in a way that addressed their individual differences. They were of the system, yet subsystems of it. I was not teaching to a predetermined outcome, as might a teacher whose practice was informed by a traditional sense of curriculum. Rather than ignoring or seeking to minimize the impact of the fact that my students were bringing very different backgrounds and concerns to the class setting, I sought to embrace their diversity—and, therefore, to expect that they not be doing the same work or generating the same products. They were all keen to write and share their stories though.

And they gained much in the way of "knowledge" during this study, as evidenced by their increased story lengths, their improved grammar and spelling, and their stated surprise at how different all their stories turned out. They thus gained a working understanding—that is, an understanding that did not bifurcate mental and physical activity —of the term "divergent." At the same time, they were building awareness that their differences were of vital importance—that is, that dissimilar traits, experiences, and opinions are the source of a necessary diversity.

It bears emphasizing that this embracing of diversity is qualitatively different from the currently popular curricular goal of increasing awareness of racial and social diversity. In the latter project, "diversity" tends to be regarded as a static feature that is often the source of discord—and, hence, a diversity that must be accommodated and tolerated. In my classroom, the diversity about learners was a dynamic source of creativity and possibility.

Diversity, then, was no longer seen as the basis of judgments of good or bad, better or worse. Students thrived in the permission to get their ideas out without having to worry about criticism or fitting their writing into a correct structure.

Theatre Sports

As with the process writing, my perception while watching the students do the theatre sports exercises was that they were all intensely engaged for the greatest percentage of the time. They were thriving in the extemporality of the teaching/learning process. The chance to work with the ideas generated in the moment, as opposed to laboring through some disembodied collection of facts contained in and dictated by texts, was motivational to them.

In the game, *Never Mind That*, they took turns for about five minutes and then switched with their partner. They also did a variation where they told stories using the palm of their hand as a map and the partner interrupted them to ask what this or that path led. While they felt they were "playing" a very good game, I saw them further developing the components of story-building. In a peripheral sense they were again learning that ideas and systems of thought are contingent and open to change, depending on which questions are asked and when they are asked. There is a learning that occurs in the margins of a lesson. The indirect consequences of a teaching and I felt that theater sports fit this. The students were doing theatre sports games, but they were becoming just as aware of how small alterations introduced by any one of them altered the play's direction. One of the boys summed up his excitement about the games:

Brad: It was cool because you have to change the track of your mind all the time and you get your mind going and so you are exercising your mind and that helps you think faster and better so in other words you are exercising your body. So you feel stronger on the inside and remember a lot more.

Some students thought that the theatre sports games were great, but unusual. Because the activities validated aspects of themselves they thought were "weird," they decided the games were weird.

Ava: The [theatre sports] game is cool because it is weird and I like that because I am weird but I don't really think that it is a game. I think you are training us to think about meaning and to get us to think faster.

They were very intrigued by how all the imaginations in the room were different and how the story seemed to go off track yet turn out all right in the end.

> Ming: Plus: I like doing [the game] *Die* because I can make different stories when I am with other people. Sometimes you think that the story will turn out bad because it has a bad start but at the end things turn around to be the best story you have made. Minus: Sometimes it doesn't turn out the way I like it because the other person goes on a different way with the story. Interesting: It is interesting to hear what other people have to say in the story. What is in their imagination.

Increased awareness of the mind's coemergent nature ...

> Ayush: It was very interesting because it [the ideas] just pops in your head even when you don't know an idea ... in a while it just pops in.

Students demonstrated they now had a "knowing" about the term "divergent" they had learned during the 5-minute writing and were now using it to describe the processes and events of theatre sports in their conversations and writings.

> Kit: I think that *Never Mind That* is a very good game. The reason why I think it's good is because it really makes you do a lot of divergent thinking, and it is also quite humoring too. Your mind diverges everywhere. It is amazing what your mind can do. When your partner says 'never mind that tell me about school' it is like every time your mind is talking about a subject it has to stop to pick another and then another topic etceteras and etceteras.

The idea that it got your mind going and quieted the editing function seemed pretty exciting to some of the students. The following comment was made by a girl who was generally shy and reticent:

> Ava: I like this game because it drives you coo-coo—then you go insane! but it helps you think really really fast and you can say anything you want and I just can't stop when I start saying words. It is one of my favorite drama games and I like drama too.

The students had clearly gained a good idea of what divergence is at this point, and they were demonstrating peripheral thoughts about how the normal thinking process could be disrupted to create other ways of being and knowing. Some of the students were sensing that what occurred in the mind influenced the body and vice versa—events and understandings that I interpreted as a move into enactivist mode of thinking about thinking, without the formal theory.

The Stone Game

When listening to the CBC - radio show guest, Joseph Schaeffer, discuss his reasons for designing the Stone Game, it seemed to me that the activity was a way of exploring how collective patterns inevitably emerge—even if the participants have differing philosophies. Seeking to prompt the understanding that it is safe to engage with another being's existence without seeing such engagement as a threat to one's own being, he had structured the activity in a way that involved adults in racial discord sitting on floors working out their differences via processes rather than programs. Even when the participants were reluctant or hostile—such as occurred when one officer stood and threw his stones down while the rest of the group sat—a pattern of stones emerged in the joint activity of the rest of the participants. The pattern transcended the hostility and emerged with an organic beauty of its own.

The sort of process that occurred in this setting is described by Humberto Maturana and Francisco Varela (1987) as a matter of *structural coupling*. Structural coupling is kin to the processes of coemergence or coevolution. The notion is used to point to the difference between a living and non-living system—and also addresses how a system develops, based on a participant's responses (as opposed to its reactions) with the other agents that it is engaging with.

> Kicking a stone and kicking a dog are two very different stories, as Gregory Bateson was fond of pointing out. The stone will react to the kick according to a linear chain of cause and effect. Its behavior can be calculated by applying the basic laws of Newtonian mechanics. The dog will respond with structural changes according to its own nature and (nonlinear) pattern of organization. The resulting behavior is generally unpredictable. As a living organism responds to

> environmental influences with structural changes, these changes will in turn alter its future behavior. In other words, a structurally coupled system is a learning system. (Capra, p. 219)

The R.C.M.P. officers who were taking part in the game had the opportunity to structurally couple in a simple exchange. In their responses to each laying down of stones they were able to relieve some of their fear that the person from the "other" cultural group was somehow a threat to themselves—in this case those who wore turbans versus those who didn not. The host provided an opportunity for a group of people to move out of what complexity theorists would call a "locked-in state." I approached my own teaching with the same desire to prompt a shift in my students' perceptions—without seeking a particular outcome.

In the classroom version of the Stone Game, the students worked in groups of four or five. They each got a pile of stones to spread out on their section of the classroom floor. They liked the stones and immediately began to collect little piles that appealed to them individually. All but one group followed the directions to take turns. Some distress came about over certain people taking too long to place stones, leading to feelings of boredom in other participants. The group that didn't follow the directions put down handfuls at a time and definitely came up with a pattern that looked more thrown together and less organic (Figure 4). The key instigator (alias: the "bifurcation point") for the divergence from the directions told me he felt the process of taking turns was just too slow for him. The rest of the class just got involved in the activity and chatted with each other while waiting. After about thirty minutes they began to use up their stone piles.

All over the classroom interesting patterns were emerging (Figure 8) and some were merging with each other as they bumped into the next group. The group dynamics in this became quite interesting. Two groups made an interesting link between their two "systems" and began to work together. Another two groups were on the verge of doing the same when one of the members assertively delineated her group's pattern from the other groups and defined their respective territories. She effectively became the "stop mechanism" that one finds in systems. The agent that defines the parameters of growth and holds the pattern into a specific limitation.

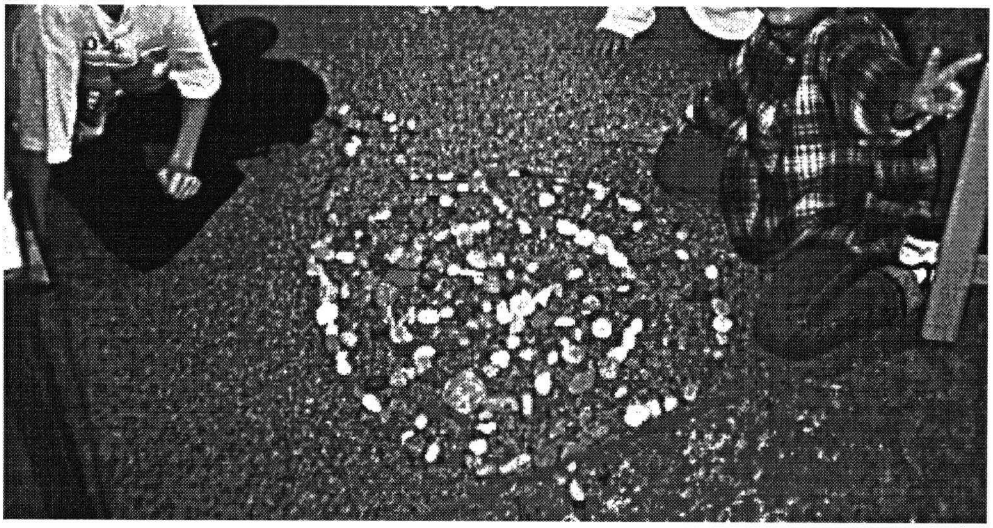

Figure 8: Stone Game Pattern

It was interesting to see that one child out of the two groups overrode their initial move to merge. She was a strong personality in the class and quite assertive. The other three students in this case deferred to her authority. The groups that had merged stopped there and did not move to encompass any other group. This may have been because it would have required a conscious act where as their merger had been more like a natural drift situation. The next group was a little farther away and it would have required more dynamic behavior than the group possessed. I never discussed this observation with the students because it seemed to me to be based in theory we had yet to lay enough foundation for but for myself it made clear the potential of such a seemingly simple exercise and I put it away for future consideration.

We left the patterns on the floor and I decided to pursue what was emerging as a discussion among the students of what each stone pattern looked like. I requested of the students to go around by themselves and look at the four patterns on the floor, and then to write down what they thought each looked like in their response journals. We then made a large chart on the blackboard of what they all saw (See Table 1).

Table 1: Students' Interpretations of Images from the Stone Game

1	2	3	4
Bunch of faces	Dog	Umbrella (2 times)	Snowy day
Caveman painting	Tree with bugs	Leaf (9 times)	Wave and water
Superhero	Chicken	Bug	Bug
Lots of faces	Bald Eagle	Bug on its back	Tea kettle & coaster
Silly faces	Bear standing	Egg	Old man's head
African masks	Ice Cream Cone		Alien (2 times)
Man with big hat	Cookie Monster		Alien with hump
Mickey Mouse Hat	Ancient City Map		Elephant (2 times)
mouse	Cow		Fat man running
	Beehive		

A class discussion ensued about how we had quite a few similar interpretations of some of the patterns—such as nine people thinking that the third pattern looked like a leaf and most people seeing a face of some kind in number 1. But others were subject to more diverse opinions. This led into the introduction of the word "arbitrary," and some thoughts were discussed about how, through a process of coming to group consensus, symbols come to mean something specific. The students familiar with Chinese writing noted that this could have been how that language developed.

The Stone Game was completely emergent in the study yet it came to be a good way of looking at patterns and systems. I had initially expected that the activity would prompt students to look at their relationships to one other (as had happened with the members of the R.C.M.P.), but the students began to discuss the patterns they were making and seeing forms in them instead. They were structurally coupled in their activity—but that is not where the focus of their interest emerged. Rather, they ended up categorizing and then comparing what they had each seen, as listed in Table 1. The learning unfolded from the dynamic in the room generated by the students' actions and observations in those moments.

In their response journals students put forward the following comments about making the patterns:

Ming: It gives you a chance to relax and let your mind go free.

Mike: You can create a different picture just by adding one rock or by putting them in special places.

Brad: We knew what we were doing right away! We were making a girl but the funny thing is we didn't know what we were making. What I mean is we didn't tell each other what it was but it was pretty obvious. Everybody knew what it was. ... We put a lot of imaginations on it and that is good fun (Figure 9).

Figure 9: Stone Game Pattern

Ayush: It [the design] just popped out of nowhere. ... It [the Stone Game] can make you think, and make you see what is inside of you and what is outside of you.

Ava: You can see many different things whichever way you look at them.

Kit: I think it is interesting because everybody is making their own thing and it is really interesting at what it turns out to be.

Many of the students were intrigued by the way that the designs just "popped" out of nowhere, how they came to make a form via non-verbal consensus, that they could all be pursuing their own ideas and yet create an interesting form of value to everyone. That their minds are "free"—free for a moment from the pressure to absorb someone else's world view I suspect. Varela, Thompson, and Rosch (1991) describe this kind of freedom in the context of their description of mindfulness. It is not a freedom for the egotistical self to do whatsoever it pleases, but rather "to be progressively more free is to be more sensitive to the conditions and genuine possibilities of some present situation and to be able to act in an open manner that is not conditioned by grasping and egoistic volitions" (p. 123). Freedom in this context is the opportunity to be involved in coemergent phenomenon occurring in the present tense. While the information of others may play a part in the students learning it will be in the context of what is occurring in the present for the students and not be an attempt to place the students in a past or future they have no possibility of ever accessing. The students are the agents of the system and are therefore able to enact the possibilities inherent in the moment creating a freedom of thought and movement.

Some students directly questioned if this was "educational," perhaps because it was devoid of the kind of outcomes and pressures that they have come to associate with school. The loss of freedom is endemic in schools, and when given the option to have a moment of self-directed learning they are faced with a feeling that they are not working:

Jie: The art part of it is very interesting. It is my favorite part of the activity. I think the stones are fun and interesting but I can't see how they could teach us much.

Ava : What I don't like about it is it's sort of a waste of time ... because all you can do is stack rocks and make a model of something. I would rather stack play dough or clay.

The exercise was viewed by these students as play—and play and work seem not to be seen as synonymous in many of these ten-year-olds' world views. I received a few similar comments during the theatre sports activities. The sad part is that, unless these children are feeling under some sort of pressure (such as working toward a test), they have learned to question the appropriateness of the activity against a narrow, but pervasive and resilient, conception of "school." The activity lacked the linear structure, the well-defined ends, the discernible bounds of the school tasks they have been trained to expect ... and so they could not locate this activity in the matrix of their understanding. It just did not fit.

We did stone activities twice and then put them away, moving on to fractals. In retrospect it feels like the study reached a fork in the path here—a bifurcation point. The portion of the classroom events that were structured around the theatre sports, the writing practices, and the stone games highlighted the role or experience that an agent in a system might have. The fractal portion of the project, as developed below, highlighted the more methodical and systematic aspects of the learning. The students continued to "input" the variables—so events still emerged from their interactions—but there was a sense of being less personally involved in this part of the study. The computer seemed to be doing the acting, and the students' roles were more toward directors than actors. They were still structurally coupling with the system, but that coupling was not the focus of attention. As with most of life, it once again became the transparent ground of activity.

Fractal Geometry

Paper, Rocks and Scissors

All of the students made the paper cuts fractals, as shown in Figures 10 and 11. As might be expected, they were all very excited to learn how to create these pop-up structures. In fact, having observed me practicing making them a few days before, the students were waiting to make them.

In my introduction to the activity, I explained that they modeled successive generations of the same form—a prelude to discussing self-similarity.

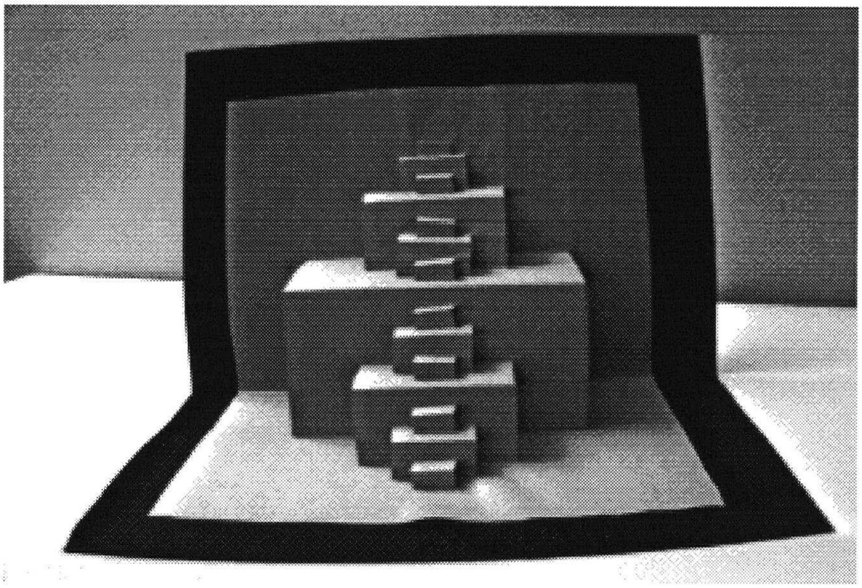

Figure 10: Central Quartile.

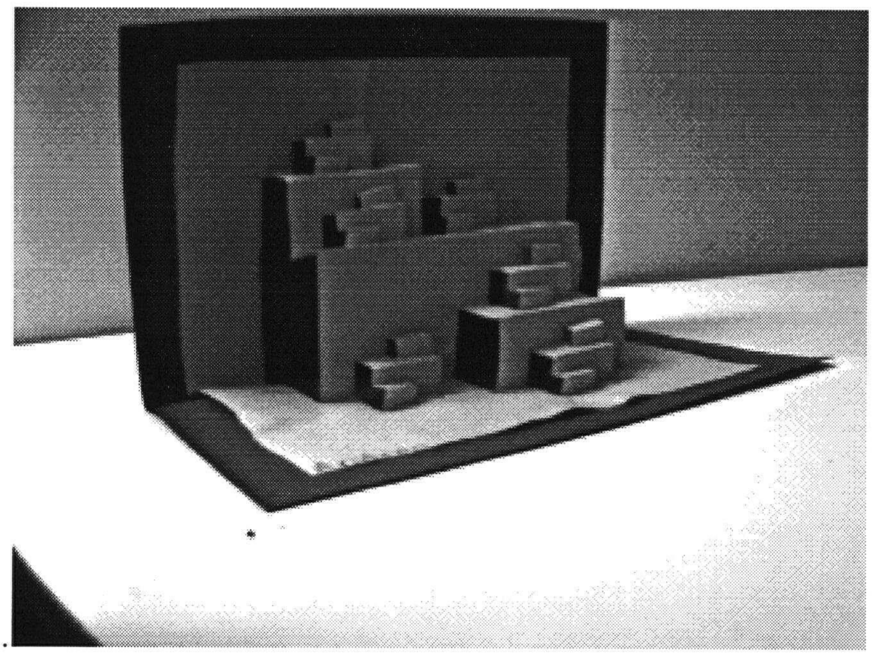

Figure 1l: Alternating Steps

We also talked about how patterns like this can be found in nature. I used the example of the coastline of Britain (as mentioned in chapter 2), as put forth by Mandelbrot. This notion of ever-increasing lengths got the children talking and they liked the idea. They knew you could measure a coastline, but they have all looked through microscopes and so they were also aware that things that look straight are not when put under closer scrutiny.

They were intrigued by the idea that the coastline could never be exactly measured. One girl brought up the example of when you catch a reflection of yourself looking into a mirror and that is caught in a reflection and the images go on getting smaller and smaller—maybe forever. She was linking the notion of infinite patterns nesting inside other patterns be they coastline or a reflection. She was indicating her increased knowing of a complexified way of perceiving the world.

When they did the cuts, several of the students who do well at academic work, as traditionally conceived (like computation and reading/writing), did not have the same kind of coordination and patience as a group of my Learning Assistance Center (LAC) attendees. These LAC students frequently struggle with "regular" classroom requirements. But with the fractal cutting, all of the students who attended the math and language LAC group excelled. It is a tactile, hands-on activity, where a different kind of knowing is made apparent. These students who have a difficult time demonstrating their knowledge so much of the time demonstrated it with scissors and the action of folding quite well.

One of their mothers came by to tell me that her son (who was one of my diagnosed Attention Deficit Disorder (ADD) students) was working away at home making the fractals and explaining the concepts to her. He commented in his journal that he was finding the work hard but that it was also engaging him:

Oscar: I liked the paper fractals but they sometimes got a little annoying because you can't do one part of it or the folding is hard.

His mother was very pleased that her son could get a sense of accomplishment from an activity that was identified as "mathematical." (He also did very well on the Logo later on.) What he wasn't great at was memorization of formulas: He could do it, but needed many reminders to master a formula and he was slow moving. He was one of only five students who went on to make a fractal (Figure 12) which is far more complex in its folding than the others. The construction of this fractal cut was an extra assignment, intended for those students who were moving ahead of the rest of the group.

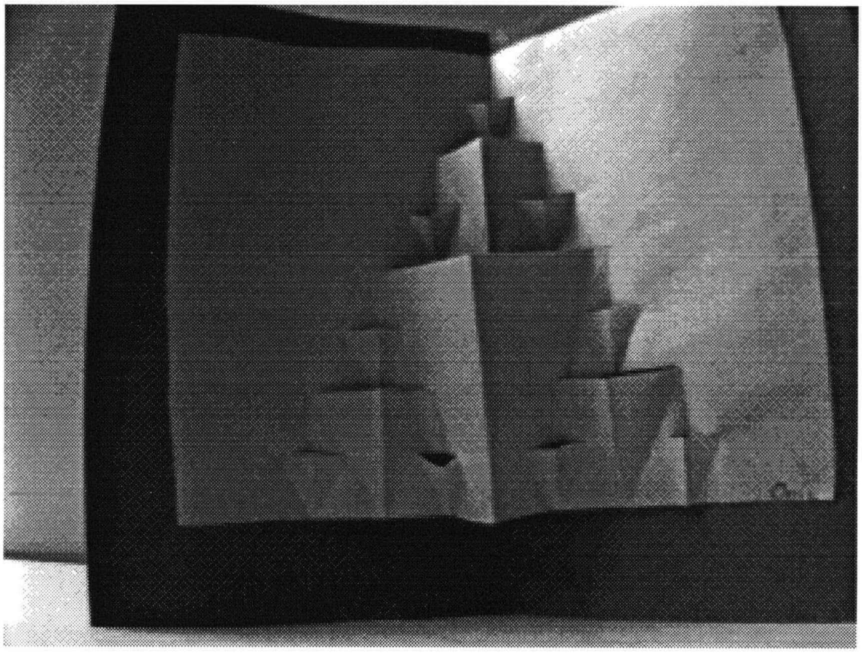

Figure 12: Sierpinski's Triangles

Both of the activities in this part of the study—that is, both the construction of paper fractals and the identification and collection of samples from outdoors—emerged in the process of the study. The collecting outdoors actually came about as an extension of the paper fractals. At some point when cutting fractals I suddenly decided that the students were probably ready to go outdoors and examine their world, looking to see if the idea of fractals really had any utility outside of the academic setting.

When we went outside I gave them a few guidelines and then allowed them considerable time to look for samples that demonstrated fractal-like patterns. The students spent quite a bit of time just looking and discussing among themselves the sorts of objects that did and did not seem appropriate to the task. They eventually came up with an assortment of plant life, including branches, pine cones, flowers, leaves—and even patterns in bark. A few students collected rocks.

In their gathering, all demonstrated at least a basic grasp of self-similarity. A few mixed up tessellation concepts with self-similarity, having studied tessellations in art the previous year. For the most part, their classmates corrected their misconceptions by explaining how one was a repeated pattern of the same size and the other involved a reducing or a getting bigger with each generation. I was impressed that the students had such a well-developed understanding of self-similarity. The complex system that I referred to as "my class" was moving into a higher order of functioning, where each agent/sub-system was participating in the acting/knowing of the other agents—and, in that participation, was moving toward a more complex form. They were co-evolving.

The hands-on cutting and folding of the paper fractals had allowed students to physically enact their knowledge. Their actions in the cutting had contributed to a physical knowing that was reenacted and further articulated again in their seeking of samples from the school yard. Their abilities to identify and select fractal-like structures indicated well-developed awareness and understanding of self-similarity and fractals, all gained in such a short time. The one activity supported the other. The concept of self-similarity now had a well-articulated relation to their everyday lived world—and this, in turn, further enabled the learning. Students' knowledge was demonstrated in their actions—or, more appropriately perhaps, the inseparability of their knowing and doing became apparent—as they went about the school yard discussing and choosing samples. From my teacherly perspective, it was a wonderful lesson—in that learners were very interested, they demonstrated that they had a good idea of what complexity theory was about (through their abilities to speak to the whole group about the concepts, as well as to discuss and debate about samples).

Later that week, when they chose the sample images that demonstrated self-similarity from magazines and wrote up their thoughts about how they demonstrated self-similarity, it became even clearer that every student had a reasonable understanding of the concept. The following comments and representations of students' work (Figures 13 and 14) are indicative of the level of understanding of the class at this point. Students were quite clearly able to see this geometry in the world around them.

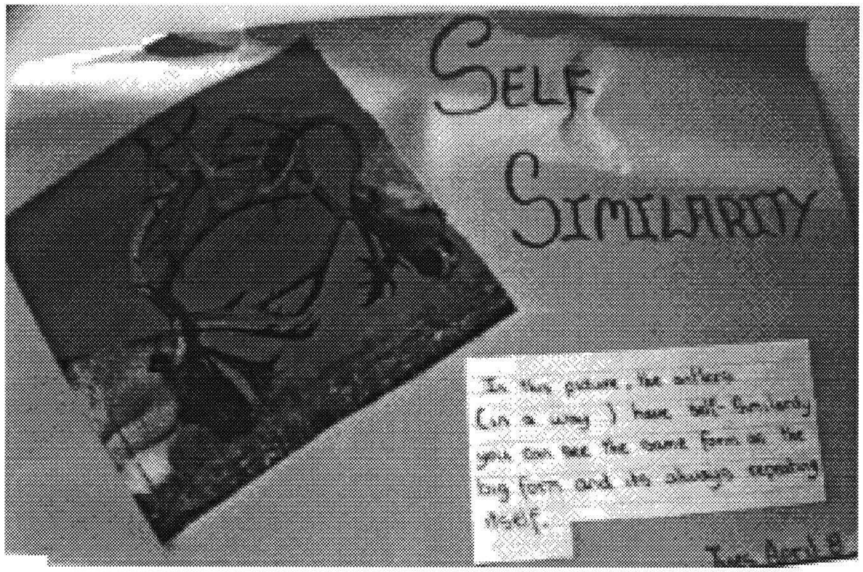

Figure 13: Self-Similarity Sample: Antlers

Claire: In this picture, the antlers (in a way) have self-similarity you can see the same form and its always repeating itself .

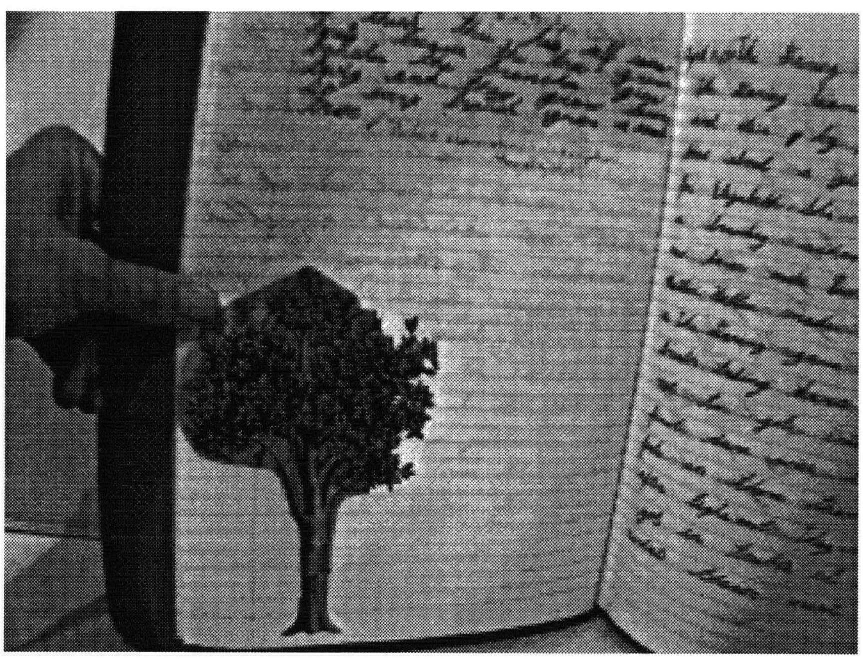

Figure 14: Self-Similarity Sample: Tree

Kit: I think this has self similarity because the tree grows branches, the branches grow twigs and they grow leaves so every branch grows a small tree.

Some students had begun to analyze the difference between the fractals of the natural world and the fractal images generated in the paper-cutting activity. Most obviously, students were becoming more aware that the straight edges of the paper fractals were simplified approximations of the scabrous fractal edges of clouds or trees. The world that these children were seeing was now perceived differently from the one they saw before learning of fractals and self-similarity. Their "knowing" had changed.

Elly: It was neat to see how nature was different in making fractals than humans.

This student was astute enough to note the difference between the paper fractals and the ones that emerged in nature. As well, the student who selected the elk antlers (Figure 10) also qualified her comment with a note that it was fractal-like. Both of these learners were articulating a sense of the perfection of the geometry versus the imperfections in the lived world —or perhaps the imperfections of the geometry and the perfection of the lived world. This was not something that I had spoken of directly, so it was emergent in their own processes. They appeared to be beginning the process of generalizing the information and applying it beyond the context of our specific lessons.

Logo Programming

I was not sure if students would be inspired by the planned explorations of Logo or find them "boring." For some reason, my initial thought was that they would struggle with the Logo activities.

I was incredibly wrong. I had based my inference on their behavior towards "textbook math"—that is, that plodding approach to school math that usually involves, almost literally, having to push learners every step of the way to learn long division. But this was not the case with the Logo. Students took to it with an amazing enthusiasm. Like the lessons described above, students' thoughts and actions demonstrated continued inspiration and creativity.

In the very first Logo lesson, one of the students figured out that changing a variable in a very simple command could transform a program that made a square into a program that drew a circle. He had quickly altered the formula to make a square—i.e., Repeat 4[Fd 80 Rt 90], which I had provided—to one that took smaller steps, turned through smaller angles, and repeated the process many more times—i.e., Repeat 200[Fd 2 Rt 2]. (In fact, this program generates a 180-sided regular polygon. On the computer screen, however, it appears to be circular. The first half of the image generated by this program is shown in Figure 15.) From there, he had begun to explore what else he could do.

In response to their requests, he also showed the students around him how to draw the circle. Very soon the rest of the class had caught this interesting variation of what they were doing. They all began making changes in the original program and finding that all of their circles and squares were different than each other's, depending on what values they entered into their programs. By changing the value of the "Repeat" command to a much higher number and reducing the value of the "Forward" command, for example, they created completely different dynamics.

This was one of those extemporal situations where the lesson is swept up by the students while I endeavor to just get out of the way, watch, answer minor technical questions—like reminding them to put spaces in the formula and to spell correctly. They were all over the room, exchanging information with each other; they were chattering away about their findings and then returning to their own computers to add to their creations what they had learned from each other. They stayed with this for the full hour and seemed to have no desire to stop until dismissal time arrived. I in no way had planned this outcome. In fact, the situation relegated me to the fringes where I was quite happy to watch and listen. It was very engaging to observe that what I had planned to "teach," was instead "created" by the students themselves within the classroom's proscribed but not prescribed, dynamic.

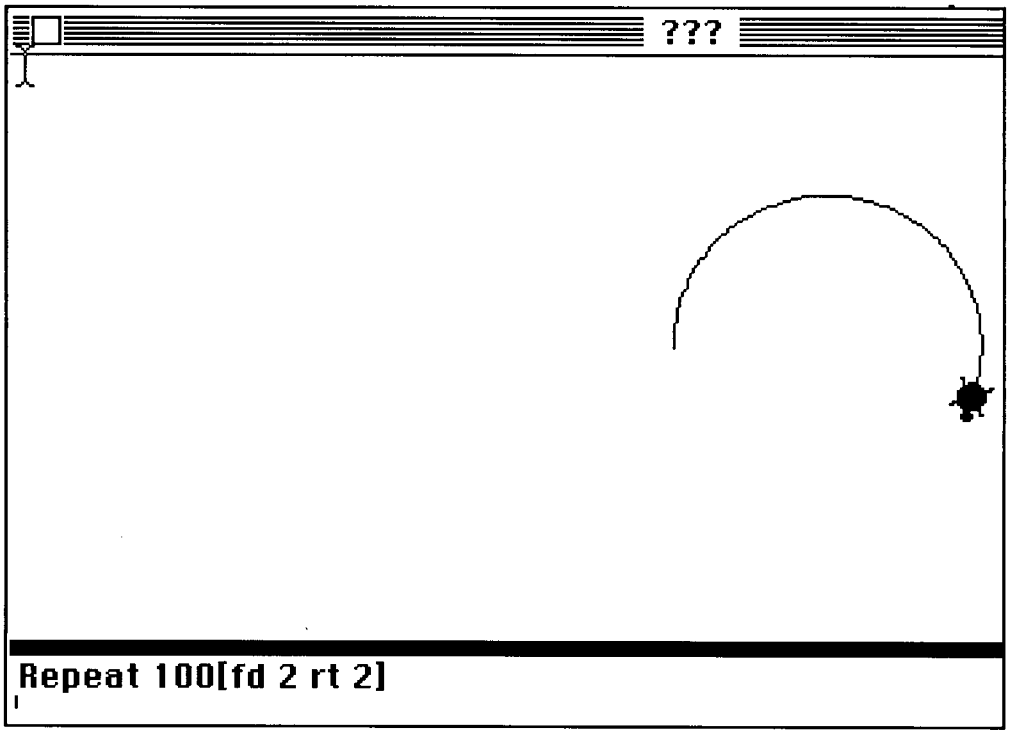

Figure 15: The First Part of the Circle Program

The "learning goal" I was aiming for in the lesson had been to look at variables and the shifts that occurred in the pattern when those variables were altered. The students had found this themselves with the discovery of the circle, but I continued on with that topic because I still wanted to introduce them to how to write and save a program. The next class I taught them the formula for a square and how to use that formula to make a star (Figure 16). This held their attention for another full hour and, once again having mastered the star, they spontaneously played with altering variables to make different sizes and kinds of stars.

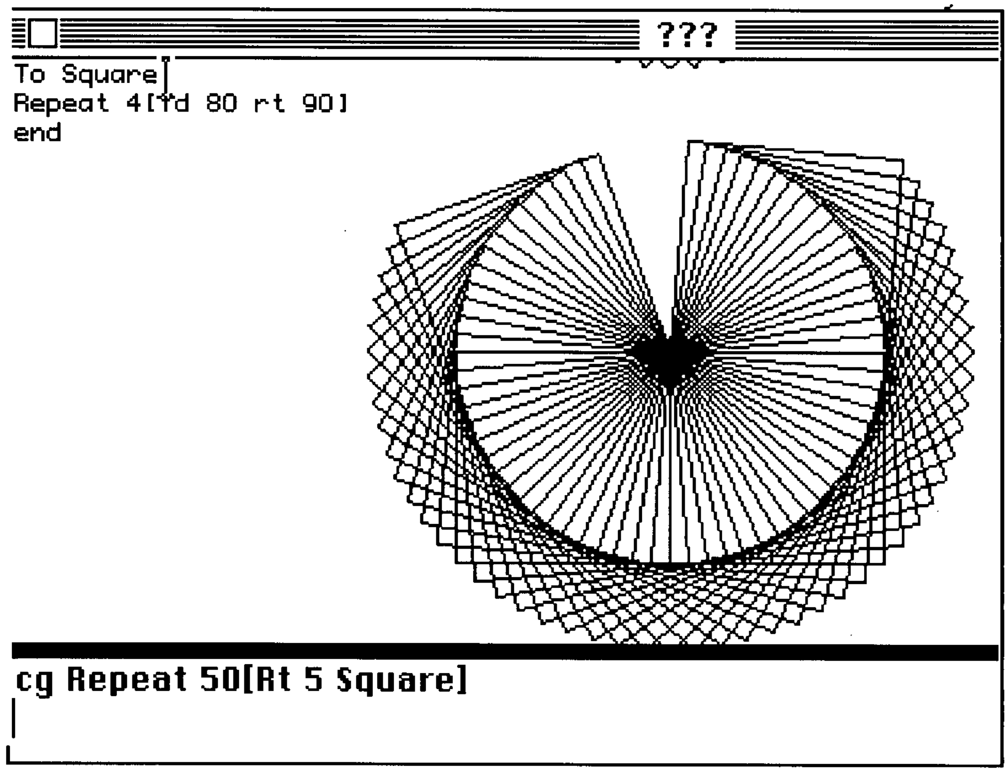

Figure 16: Using the "Square" Program to Draw a Star

In listening to discussions at this time, I noticed that they had begun to name their Logo pictures and to relate them to things like supernovas, stars, pathways. That is, as with the stone game, they were working to relate their new learning to the world they knew. They were discussing how the Logo drawings seemed relevant as a way of explaining their universe.

Following the computer class the next day, I wrote the Logo programs that worked through the development of recursive programming (<u>Program 1</u> to <u>Program 4</u> as in Chapter 2) up on the blackboard. I asked if anyone could tell me what was going on in the two formulas. I actually didn't expect anyone to answer. I was pleasantly surprised, though, when six of the students put up their hands and began blurting out what it meant—and they were basically right!

I got them to quit calling out their answers, and one of my better math students explained quite clearly that, in the first program, the star was getting smaller and smaller as it subtracted ten pixels each round. Another "fairly average" math student in the "regular" curriculum had a go at the second one and came very close to interpreting it correctly, missing only the importance of the "Then Stop" command. The importance of the "Then Stop" command was pointed out by yet another student. The discussion was involved and I was being educated on how thoughtful and observant these students really were. Here were ten- and eleven- year-old students reading a computer language that was presented in algebra-like formulas—a topic that was some years in the future, in terms of their studies of school mathematics. Most of the other students caught onto what they were saying right away, and for the benefit of those few who did not readily comprehend, we did the blackboard exercise I had intended to do in the beginning.

The final Logo lesson was the only one that had been a part of my original web chart—the designing of a formula to construct a tree. The students made various kinds of trees, some more elaborate than others, but they all demonstrated masteries of the notion of changing variables and the concept that only slight incremental changes can lead to unexpected and dramatic effects. A simple and successful example was made by two girls working in as partners (Figure 17).

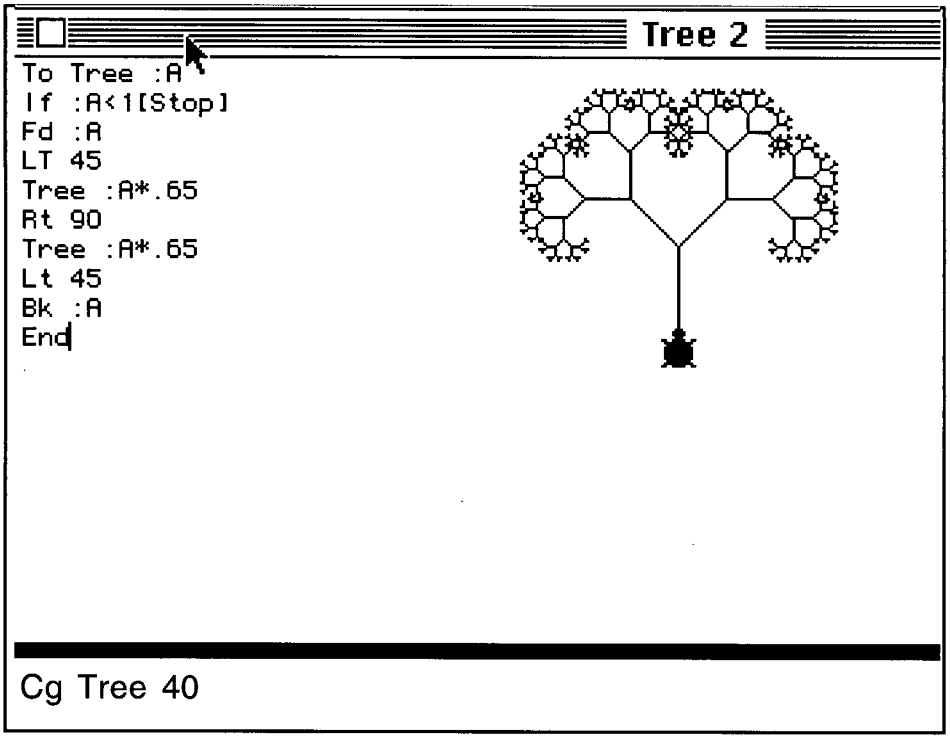

Figure 17: A Fractal Tree

The girls chose to manipulate the three features of the program: (1) the point at which the drawing of the tree stopped; (2) the size of the tree; and (3) the operation used in the program (they changed from dividing the variable each time to the equivalent operation of multiplying by a decimal). While I cannot be certain, I believe that their decisions were quite random—that is, they were likely not completely aware of exactly what they were doing, but they did understand that each of the changes they made resulted in the alterations in the tree.

As already mentioned, this appreciation of the role of variables was my main learning objective in the lesson. Yet, it is clear that these students' learning hardly stopped there—in fact, that learning almost seems incidental. It was also apparent that their understandings of algebraic manipulations, computer programming, and arithmetic operations were developed in various ways. More fundamentally, I would hazard to suggest that their conceptions of "tree-ness" changed, both in terms of the perceived structures of trees and in terms of conceiving of trees as fluid and dynamic forms (rather than solid and unchanging objects). Discussions throughout the classroom were also demonstrating increasing knowledge, as students asked questions about why the computer could not interpret spelling errors and how their game-programs were related to programs like Logo. Their journals were also showing changes in perception, as indicated by the comments from Claire, Kit, Mike, and Nat, below.

Bringing It All Together

With the bringing together of the various activities in this study, I finally told the students that we had been studying different aspects of a field known as Complexity Theory—a field, I explained, that seeks to examine and understand the unpredictable parts of living. The Brainstorming Web (Figure 6) helped make a visual map so that the students could make connections. Following this their writing began to reflect a change in perception. They were considering it all and were shifting, absorbing, and co-emerging with the new way of thinking.

Claire: Everything that we've been doing in the science of complexity has made me think a lot more about the world and nature and I'm really glad that we learned about it.

Claire's reflection on her universe and nature and might be interpreted as suggesting that she had recognized a change in her perceptions of the world around her—and her place in that world. Her comment is reminiscent of some of what Pinar and Grumet (1988) saw missing in current educational curriculum: a hermeneutic look at the contours and textures of life that are normally left unnoticed.

Kit: The butterfly effect is I think a very interesting thing in science. I mean like just one flap of a butterfly wing and it can change the weather. That is amazing. I never thought that it could be possible but I think it could be possible and that is really amazing.

Kit is referring to a true shift in perception. The idea of the butterfly effect has prompted an awakening in her to dynamics and the inevitability of change—a shift that might have the same effect in her life as the flapping butterfly wings can have on the world's climate.

> Ava: I really liked everything this year. The games were fun and Logo is really cool. I like to talk about the butterfly effect—really cool.

> Mike: Theatre sports is like the butterfly effect because when we play Die. One person starts and then when you point to somebody different if they just say a few words it can change the whole story! Theatre sports is so fun.

Mike made the connection between the complex unfolding of theatre sports events and the consequences of changing the values of variables in Logo programs. Given the rather sharp distinctions that tend to be drawn among mathematics, the performing arts, and science (especially in formal educational settings)—and considering the frequently mentioned dichotomy between school events and "real life"—I regard Mike's comment as indicative of a great accomplishment in generalizing information to make sense of lived experiences. It also indicates an understanding of the complexity of systems—and an apparent joy (rather than dismay or a worry) in the surprises inherent in it.

> Nat: Logo is very fun because it can make self-similarity shapes or make weird circles. The program is teaching you shapes that you have never seen before like maybe a dandelion that repeats itself.

Nat is correlating the fractals to how a dandelion might possibly be constructed. The student has made the link between how the theoretical might assist in making sense of the actual.

These students were merging their knowing with the new notions of living in a changing universe. They were intrigued by the idea and I felt they had a sense of its influence on the world around them. I had only wanted to introduce them to the possibility of this very different way of seeing, and had felt all along that it would be the kind of information that made sense over the years (not simply over the duration of the study).

These learners were only grade fives, and I wasn't expecting them to grasp the full depth of the subject. I was most pleased to see them actually grasp so many of the concepts and then begin to demonstrate a thoughtfulness in their writing and conversations about the influence that complexity theory and its sub-discourses (like fractal geometry) might have in the perceived and conceived world.

Chapter 4
Interpreting a Complex Curriculum

In the project described in the preceding chapters, the curriculum-as-lived had a recursive structure. Like the infinite nesting of an image inside of an image that occurs when standing between two mirrors, the elements of this project were recursively embedded. Serving as both the focus of study and the framework for interpretation, complexity theory became both the image and the embedded image of the investigation. It explored teaching extemporally while also introducing a new topic/subject into the curriculum. Among the recursive layers of the project, one was a variation on complexity as it applies to students' knowing; another was the manner of teaching (which was intended to be enactive, complex, and open to emergent phenomena—that is, extemporal).

In this closing chapter, I look briefly at these layers: students' learning and the extemporality of teaching.

Complexity as Curriculum Subject

As described in Chapter 2, the "curriculum" was not conceived as a linear progression; nor was it thought of in prescriptive or predeterminable learning goals. Rather, it developed in cycles of thought with leaps into innovative thought. However, while it was not a linear progression, a retrospective examination reveals that the experience did seem to progress from one lesson to the next. Writing, for example, quickly emerged as the place to start after first meeting the students. The progression from writing practices to theatre sports to the Stone Game now seems "natural" —and a logical introduction to the study of fractals. In spite of the now-apparent sensibleness of the sequence, however, the unit was hardly "planned," in the traditional sense.

The sustained writing practice and the theatre sports provided the students with an opportunity to hone their writing skills—which I felt were needed for them to be able to express their ideas in their response journals. It also encouraged exploration, giving each person a permission to be spontaneous and self-directed without being out of control. An example of education in an environment of liberating constraint.

The students enthusiastically engaged the academic challenges that developed in this milieu with an accompanying improvement in their academic skill. Their writing increased in length, their ideas got progressively more interesting, and they developed trust in their ability to read out loud, perform in front of their classmates, and make what might be considered mistakes by some. These activities therefore worked well in supporting literacy as outlined in the Provincial Language Arts Curriculum.

The first section of the study, which included the Stone Game, was largely developed around the notion of "divergence"—an idea that, as interpreted through the lens of complexity theory, was new to students. We ended out discussing different talents and ways of thinking in this context, and I attempted to use it to put class members more at ease about demonstrating their own unique perspectives in the writing, theatre, and stone creations. They came to understand the concept of "divergence" during the theatre sports, as demonstrated by their continued use of the term in their discussions for the rest of the year:

> Jessa: In branches on trees new branches diverge everywhere. See picture number 2 (in her magazine samples) ... Notice! you must look very hard, the large stems branch off to smaller stems. WOW! self-similarity.

They absorbed the concept of improvisation as an access to the potential of the mind also. They began to question their mind and what it was:

> Adrian: The hand stories (an improvisational game) was really fun because someone gives us a subject but then other ideas just pop right into our heads. We don't think about them – they are just there ... It is a fun because we find a lot of new things in our minds.

These students had begun to integrate critical components of complexity theory and enactivist thought. While the terms "divergence" and "improvisation" are not used much in complexity theory—they are fundamental to it. Bifurcating systems are diverging systems; self-organizing systems are improvising—that is, adaptive, co-evolving systems.

The students were ten years old. I did not undertake to explain the depths or the intricacies of complexity theory or enactivism to them at the start of the year—that would have been like expecting them to grasp the components of a novel by Jean Paul Sartre by telling them that he and his associates wrote books about the uncertainty of life and existentialism. Rather, I attempted to create the conditions to allow them to learn in a manner that was appropriate to them. I do feel, had we the chance to continue the following year, that we could have prompted an increased sophistication of their understandings of complexity theory. They had developed an adequate background by the end of the seven months to grasp "complexity theory" as an umbrella term for looking at systems that change—making, for example, connections such as Mike had (p. 75) between the differences in theatre sports games and the altering of the values of the variables in a Logo program. Elly (p. 68) supplied another example of making linkages and observations by noting that nature makes fractals differently than humans.

As I stated earlier, I do not think that what the students learned is somehow sitting in their memory as a collection of bits and bytes to be plugged into conversations. The knowledge, rather, is more experiential and knitted into their ways of being in the world. It is something that will exist in the peripheral part of their formulated knowing, and it will alter their understandings and ongoing interpretations of their lived experiences in subtle but important ways as they continue to mature.

In their year-end comments, these students were being more hermeneutic: Their journals were revealing a thinking about "the contours and textures of the life we are already living" (Jardine, 1992, p. 116). They were applying this shift in knowledge to their lived world. Both Claire on (p. 74) and Nat on (p. 75) provided articulate quotes of this shift in thinking.

Within the students a "knowing" began to develop. The knowing was more than the acquisition of some new data about fractals or systems, it was more akin to gentle bifurcation in their thought process—a shift in perception born of the introduction of a new thread of thought one which would be woven and rewoven into the multifaceted fabric of their way of being. I felt the shift was subtle and would become apparent to them via their very personal journeys in life. The knowledge attained would add to their unique blend of being as their life unfolded over the years and was not the kind of information tested for at the end of a term. They might never trace their awareness of the dynamics of living systems back to what was done in a series of lesson they were a part of in 1997. The shift in perception was evident though and would assist them in covert and perhaps overt ways in the *running of the course* that was their lives .

Davis (1996) discusses Pinar and Grumet's use of the term *currere* as the root word of curriculum and its initial meaning as that of *running of the course* rather than curriculum being the *course to be run.* In this context he notes that "in rendering experience meaningful, one recovers and recreates one's history and simultaneously creates new possibilities for one's future" (p. 90). In terms of this study the students were not held accountable to a "curriculum" they must run to succeed but instead were given a new way to run and that in itself was curriculum. What they were given was information that they could run with for as long as they found it relevant. It was open ended, divergent, and fostered improvisation and extemporality. It was founded in a sense that the students would enact their knowing long after they passed the point they shared with me in time and space.

I felt the students gained a small but important experience in the extemporal way of being—in enactivist or complex ways of perception. They were able to experience being a part of a system that was moving and changing via the writing, theatre, and stones, and they were able to theorize and work toward more analytical understandings through the fractals and the other year-end activities. They then applied these new knowings to the circumstances of their own lives, as indicated in the comments about their own thinking, their perceptions of dandelions and trees, and their mulling over of what mathematics might really be if its interests could extend beyond numbers and lines to include the likes of theatre sports and the making of fractal images.

Extemporality

What has always seemed wrong with formal education, from my perspective, is the notion that a unit of study can be fully pre-planned and that it can be implemented just as it has been written down.

My years as a teacher—and my life as a learner—has taught me otherwise: Such pre-stated lists of objectives can not be met. Yet, in a society that insists on predictability and linearity, this myth is pervasive—so much so that we are currently witnessing a situation where a teacher in North Vancouver, British Columbia—has been sued by a parent for not meeting all of the objectives of the overview that she handed out at the start of the year. This conception of fixed and pregiven curriculum is aligned with an understanding of the learner as somehow partial or incomplete upon arrival to the class in September. All we do as educators is fill them up; we are educational gas pump attendants. The metaphors and assertions of the Newtonian paradigm (e.g., the universe as a machine; all events as the logical and predictable consequences of prior events) are taken to a point of total literalness. It promotes a scenario that then sees the world as made of objects. Therefore the mind is an object. And so, it follows, if one can deposit knowledge objects (comprised of words, numbers, and pictures) into students' minds, they will become tools that can be manipulated and used to construct an internal model of an external world.

That this attitude toward learning is an unviable one is apparent in looking at the makeup of any class. First as has been indicated by researchers such as Maturana and Varela, learners do not arrive with empty heads or worlds ridden with holes. Neither are their minds separate items from their bodies or their environment. Rather, minds—like knowing—are processes not, things. The process that is the mind evolves in tandem with its environment. It reflects every tactile, visual, and other sensory experience that the cognizing agent has in coupling with the environment—and from the masses of sensations that occur within the bodily system. We select and define what is relevant from the randomness of life, at the same time determining and being determined by our relationship to (that is, our perception of) life.

To try as a teacher to "override" a student's own experiences with one's own presumed superiority seems a gross misinterpretation of one's power—not to mention, a profoundly troubled conception of human relationality. As Maturana and Varela concisely point out through their findings in enactivism and their "knowing is being" aphorism, learning is not merely an aspect of life ... it *is* life, "every act is an act of cognition" (Davis, p. 210). The student may appear to acquiesce to the dominance of the teacher or the educational system but in reality far more is occurring. Madeleine Grumet (1995) noted the following in terms of how we have been approaching curriculum and the shortcomings of the approach:

> Because we have been fascinated with the ends of education and not the middle, we have not been teaching the basics. We have reduced the elementary school curriculum to a developmental mythology, draining the texture and wonder of the world from the books we give young children to read and from the school day stuffed with deadly age-appropriate routines. We have compensated for the emptiness of the elementary school curriculum by dedicating secondary and higher education to ancestor worship, oblivious to the world that students actually live in and care about.
>
> In our anxiety to protect, promote, and produce our children, we regularly leave out the second step. We wedge them into the base, calling it a firm foundation, and sink them into the cement of its assumptions. We prohibit their

> movement by providing no other stepping stones. They will move anyway. They will zone out, tune out, freak out, drop out. (pp. 17-18)

The results of forcing students to study a more or less "dead" curriculum of selective often outmoded data may result in acquiescence or in rebelliousness or in a quiet shutting down at school but it will not aid the students in making sense of their own world. It is here that I feel a more extemporal approach to education is essential. It allows the dynamics that are particular to the students to emerge and creates a curriculum more relevant to themselves.

This year, the members of the class that became the focus of this study arrived with a very definite personality as a group *and* as individuals in this group. This group of people, myself included, had a dynamic all its own from day one and it was a dynamic that was unique to that group. No pre-planned curriculum could have accounted for it in advance because it was born the moment we all collected together on the first day of school and maintained a changing nature like any other part of the natural, living, world we are a part of.

At the start of the year, *the group* was not very well-trained at being in a classroom: they were always out of their desks (even when I was speaking), ran all over and jumped on furniture when I left the room, yelled out, arrived late, and generally demonstrated a disinterest in academic routine. When I first began I despaired over the thought of doing my research with them.

I shared responsibilities for this class with another teacher—a colleague who, unlike myself, is a fan and active user of Behavioral Modification techniques. She implemented all of her best methods for rewarding students in an effort to get them on her side in regard to their work and their behavior. She had lots of checklists; she put the students into teams; she had "reward days"; she called parents for support when her own efforts did not seem to be getting the job done.

I did not do any of this.

At the end of the year she still had not got their overall behavior under control. I too, was still having to ask them to get out books for silent reading, to request that they arrive on time ... but they had quit running around, had stopped getting out of their desks, and were not interrupting me or one another so much. My teaching colleague felt that they were still hard to manage and we had discussions about their "passive-aggressive" way of taking forever to finish assignments. She felt they were far behind the grade five classes she had taught in previous years. They were definitely good at putting off until tomorrow that which you might do today.

In the context of my study of extemporal teaching, though, this all fell apart (which is to say, in terms of the seeing the class as a learning collective, it all came together!). When I did assignments from the math textbook—like long division, decimals, etc.—all but a handful of the students behaved with incredible reticence, off-task behavior, and actual confusion at learning the materials. When I switched over to the extemporal way of teaching—as embodied in 5-minute writing, theatre sports, fractal explorations, and other activities—they absolutely shone. They became teachers of themselves and teachers of each other. They even became teachers to the teacher. A collective exchange of ideas would emerge during the extemporal moments of the study that engaged us all. The Logo lessons where one student discovered how to program circles transformed twenty other students into innovative young computer programmers within one hour. The Stone Game created a collective understanding of how symbols and patterns in language and numeracy are arbitrary yet come to feel absolute. So much of the learning was done in a motion akin to a wave where one or two students might begin an idea but it flowed through the group in a natural, fluid, sharing. The difference between the extemporal environment versus the times I spent trying to push through the assigned math text were dramatic.

As a unit, they would go from dragging their feet as I harassed them to "hurry up"—to my being able to just watch as they asked questions, discussed and shared information, and went ahead virtually managing the learning for themselves with minimal direction from myself.

From my perspective, this has everything to do with the learning being meaningful to them. This it true on both the individual and the collective level: As a group they all felt a connection to the information and each other's sense of relevance to it. This is not to say that we had left the required curriculum behind and were off doing any old thing that we happened to fancy. In doing the fractals, students were using math to create and explain to themselves their world. They were applying knowledge they had about multiplying and dividing, adding and subtracting and learning about decimals, angles and algebraic formulas. The same with the components of language arts being in the writing and theatre. The difference is that the enactivist approach had also opened a way to express themselves as both individuals and as a group in a way that had relevance in the moment of the teaching/learning.

In being extemporal it is possible to stay in tune with both the students individually and as a group as they learn—but it is also possible to build skill. These goals are not mutually exclusive; this approach to teaching cannot be fairly called "airy fairy" education. Rather, it is *deep* education. It takes a risk of trusting the students' love of learning and the teacher's love of participating in the ongoing production of knowledge. It seeks to address both the practical skills needed and the student's own ability to think. It is enactive in that the students' actions will demonstrate what they know, what they are ready to learn next, and how one might proceed in an educationally responsible manner. The students in this study demonstrated clearly that they were ready to write full-length stories after the 5 minute writing, so we went there. They peer-edited, I edited, their parents edited, and they self-edited. Co-emergent with this was a discussion on systems and how we contribute differently, yet similarly to them. It was deep, addressed a relevancy to their lives, and they moved toward it in a way that took no force from me. They would ask over and over about when were we going to do writing, theatre, and work on the computer (fractals). Only one student asked when were we going to do math text work (which we had continued throughout the study). They were obviously learning with a relevancy to themselves and wanted to pursue those parts of the curriculum that spoke to that in themselves.

William F. Doll, Jr. (1988), in discussing the impact of Prigogine and the field of complexity theory, suggests that it is a place from which a *transformative curriculum* can evolve:

> A transformative curriculum focuses on the qualitative changes the participants—teachers as well as students—go through as they engage in the curriculum: Here curriculum is being considered as a process of engagement. ... Prigogine is one of a number of theorists in various fields who gives a perspective of reality useful for the construction of a curriculum which goes beyond stability, and into the realm of transformation. (p. 127)

It is in the definition of curriculum as a *process of engagement*, not as content, that I locate my teaching approach. It is a deeper way of seeing, shifting the focus from the concreteness of data and criteria toward the realm of exploration and trust. It is as Doll suggests in his analysis of Prigogine's work a place to move from the Modern notion of a stable state into the realm of a transformative one. This *process of engagement* is where complexity theory and enactivism both contribute to the potential of a transformative curriculum. They firmly support the knowing that living systems—those of the world, the body and the mind are fluid not solid. I have coined my own phrase to sum up what seems to me most valuable in this process of engagement and its relevance to educational theory—I call it the "Three E's"—extemporality, emergence and enactivism.

The Three E's—extemporality, emergence, and enactivism—give guidance on how to approach a postmodern curriculum based in change—a transformative curriculum. Extemporality provides the permission for teachers to follow their own intuitions and respect that of their students, that in turn allows an emergence of the knowings inherent in the group. It allows the students to then enact what they already know and what it is they really are needing to learn.

Glossary

Bifurcation Point:
The point at which a previously stable system creates a branch or jump to form a new system. The bifurcation may or may not leave the old system operative.

Butterfly Effect:
Based on climatologist Edward Lorenz's analogy that there is a potential for a butterfly to add just the right amount to a weather storm to push it a bit further into a hurricane. It is now used to refer to an agent in a system that is able to alter that system in an unpredictable way via what for it is a routine action.

Chaos Theory:
The study of patterns of change (chaos)—as opposed to patterns of stability in systems. Related to systems theory. A component of complexity theory.

Co-Emergence:
When two or more agents become bound together in a system they influence each other in ways that prompt new characteristics to emerge for each.

Complexity Theory:
Study of how systems come to contain characteristics that none of their individual agents possess. (See self organization). Applied to fields of study as diverse as economics, storm systems and human biology, among others.

Dissipative Structures:
Term describes a form of self-organization researched by physicist Ilya Prigogine. It addresses open systems that straddle the line between structure and order, on one hand, and dissipation, on the other. Prigogine researched thermal dynamics but the theory is applicable to living systems. It demonstrates how amplifying feedback assists in jumps to new forms of organization.

Emergence:
A process where previously unforeseen properties emerge in systems as the levels of complexity are increased. The liquid properties of water do not exist in its component parts they emerge from that particular combination (i.e., at the molecular level).

Enactivism:
A theory of cognition that focuses on the process by which an organism and its environment interact. For example, mind is not viewed in the Modernist notion as a detached and disembodied thing located in the observer's body. It is seen more as a process that results from the ongoing flow of information between the environment and the many aspects of the body that interacts with it.

Extemporality:
That which arises out of the context of the moment. In terms of teaching, extemporality implies staying open when working with the students and the curriculum in such a way as to develop divergence and creativity while not losing sight of core academic goals.

Fractal Geometry:
The geometry of self-similar (see below) forms. Fractal geometry assists in understanding non-linear effects such as tree branches, clouds and turbulence. It is based in both algebra and geometry.

Hermeneutics:
The questioning of the "ground of action." Critically examining that which is taken for granted and, from there, seeking other ways of proceeding that might open up new ways of thinking and acting.

Lock-In:
Occurs in a system when an agent links to several systems, each of which come to depend on its function or role. Even though there may be more efficient agents developed, they will be negated unless the role of the first is diminished in the several linked systems. The gasoline engine versus electric is a current example.

Modernism:
An historical era begun in the 1600s that extended into the mid-twentieth century. Modernist thought was based on analogies derived from the advent of the industrial era and the universalization of mathematical notions. The results being epitomized by the notion that a human being could be separate from the environment and therefore objective in thought.

Natural Drift:
Natural Drift is a rethinking of the Darwinian theory of "Natural Selection." Here organisms discard that which does not serve their purposes and co-evolve with their surroundings (survival of the fit) rather than being selected by the environment (survival of the fittest).

Process (or Sustained) Writing:
Creative writing practice designed to develop ideas as opposed to structure. Writers write whatever comes to mind with nominal editing for a minimum of 5 minutes.

Recursion:
The procedure where a system has embedded in it a command to reproduce itself — for example, a reflection that is reflected in another mirror which then reflects it back. Recursive formulas are used in fractal geometry to produce self-similar shapes.

Self-Organization:
The tendency of the agents to form a system that then engages in self-regulating and self-renewing functions. Self-organiztion leads to the emergence of an integrity or identity.

Self-Similarity:
The repetition of patterns inside of similar pattern. Self-similarity is the recursion of a detail where aspects of a form look the same under higher and higher magnifications — like the branching of a river delta or a body being full of individual cells while being akin to a cell of the planet.

Strange Attractor:
The point that attracts or dissipates a system's energy, thereby keeping it from evolving into totally chaotic patterns. A simple example, a pendulum's swing. The string holding the pendulum could be seen as a strange attractor in terms of how it determines the path of the pendulum.

Structural Coupling:
The process whereby a system interacts with its larger environment in a recurrent manner. The interactions facilitate ongoing changes in the system while maintaining its essential pattern.

Systems Theory:
A theory that posits that systems come to exist because the agents involved in them settle into patterns— they is they *self-organize.* For example, weather systems develop based on relationships to the earth's axis and distance from the sun and economic systems develop based on a multitude of factors from crop yields to trade agreements.

Theatre Sports:
Improvisational theatre games played in teams.

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